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THE OSTEOLOGY OF THE TRACHODONT DINOSAUR KRITOSAURUS INCURVIMANUS

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THE OSTEOLOGY OF THE TRACHODONT DINOSAUR KRITOSAURUS INCURVIMANUS[1]

Discovery

In the summer of 1918 the Royal Ontario Museum of Palaeontology organized an expedition to search for dinosaurian remains in the well known and prolific locality on the Red Deer river in southern Alberta. The party was fortunate in the discovery of the skeleton of a crestless trachodont dinosaur, which, on being removed from the matrix, has revealed characteristics of sufficient interest to warrant a somewhat detailed description.

The specimen was obtained from the beds of the Belly River formation in the bad lands of the Red Deer river which are most conspicuously developed in the vicinity of the confluence of Sand Hill creek with the main stream. The skeleton lay at an elevation of 116 feet (aneroid) above the river at a point about two and a half miles above Happy Jack ferry and a mile south of the river.

The animal fell or was washed by the waves on a sloping shore of sand which had a general trend of N.30°W. This old shore is now represented by a bed of sandstone containing numerous hard concretions of clay ironstone. The body was extended in a general direction of N.3°W. with the limbs towards the water, i.e., north-easterly. Waves from the open sea very rapidly buried the skeleton in white sand which has become an extremely hard sandstone showing pronounced cross bedding which dips 30°N.60°E. So

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[1] Kritosaurus incurvimanus, *Parks*, Transactions Royal Society of Canada, Third Series, Vol. XIII, Sect. IV, 1919.

rapid was the entombment that the collapse of the trunk was prevented, the ribs of the two sides and the two sternal bones being embedded in normal position. The bones of the right or under fore limb also lay in normal position with the palmar surface of the manus upwards; the right or upper limb had so sagged at the elbow that the radius and ulna occupied a position at 70° to the horizontal, with the manus, also with the palmar surface upwards, lying on the substratum at the same level with its fellow.

Some disturbance of the bones of the hind limbs was brought about by the action of waves before entombment was effected, the left fibula together with some of the metatarsals and phalanges being washed a short distance out. The right limb was less disturbed, only the bones of the pes being somewhat scattered.

Since the time of entombment the sandstone has become very hard, almost flinty in places, and a thin film of clay ironstone has formed over the surface of some of the bones. At the time of discovery natural erosion had removed the overlying rock, bringing about the exposure of the head, scapula, femur, ilium, ribs, and transverse processes of the vertebrae. The exposed parts were, of necessity, injured, but a more serious loss was occasioned by two small waterways, one of which had entirely removed the anterior bones of the head and the other had cut off the extremity of the tail. Despite these imperfections the skeleton retains nearly every feature required for detailed description, the posterior caudal vertebrae being of slight anatomical significance.

Owing to the hardness and shattered condition of the rock and the great thickness of the blocks, the specimen was unusually difficult to excavate and required two years' preparation in the laboratory. As the upper or left side was seriously injured it was decided to prepare the specimen as a panel mount showing the right or under side. Before proceeding with this operation the head, scapula, coracoid, and limb bones of the left side were entirely removed from the matrix; in the final preparation these bones were replaced, as far as possible, in natural position.

General Description

Lawrence M. Lambe described a crestless trachodont from the Belly river formation as *Gryposaurus notabilis*. The type of this genus and species is in the Victoria Memorial Museum, Ottawa. The head has been prepared but the partially preserved body is in very hard ironstone matrix from which it will be difficult or impossible to remove it. Lambe's description of the genus is as follows: "Skull large, narrow and very deep, with highly arched nasals. The lower, anterior border of the premaxillae expanded laterally. Orbit much smaller than the lateral temporal fossa. Quadrate high, partially separated from the jugal by a small quadrato-jugal. Mandible robust. Predentary expanded laterally and deflected in its hinder half, and posteriorly bifurcated below at the midline. Neural spines of the anterior dorsal vertebrae long. Ischia not expanded distally. Body covered with small, polygonal, non-imbricating, tuberculate scales of rather uniform size. [1]

In general appearance and in all essentials which can be compared the specimen under review so closely resembles Lambe's type that there can be no doubt as to the generic identity of the two individuals.

In species as well as in genus our specimen shows a marked resemblance to Lambe's type; there are, however, several points of difference which seem to indicate a separate species. In view of the considerable degree of variation known to occur in individuals of the same species of dinosaur, the present detailed description would scarcely be justified for the sole purpose of erecting a new and somewhat doubtful species, but, as the body of the genus has not hitherto been described, and as the specimen shows practically all anatomical features in excellent detail, the description seems to be warranted for generic differentiation alone.

In addition to its very strong resemblance to *Gryposaurus notabilis* the specimen has striking affinities with *Kritosaurus novajovius* from the Cretaceous beds of Ojo Alamo in New

[1]Ottawa Naturalist, Vol. XXVII, No. 11, February, 1914.

Mexico. This form was described by Barnum Brown in 1910, both genus and species being founded on an imperfect head in which the nasal bones were absent. The generic description follows:

"Skull deep; muzzle narrow; frontals short, orbital portion reduced, barely coming to the border of the orbit; nasals and premaxillaries very long; quadrate elongate; quadrato-jugal short antero-posteriorly, completely separating quadrate and jugal; mandibular rami massive, edentulous portion decurved; teeth spatulate in lower jaw."[1]

Brown's specific account is of no immediate interest as our specimen is evidently distinct and much more closely related to *Gryposaurus notabilis*.

Brown maintains that *Gryposaurus* and *Kritosaurus* are identical and this view has been adopted by Gilmore, who has prepared a model of the head of *Kritosaurus* in which the arched nasals of Lambe's type are incorporated. Owing to the loss of the determinative bones in the anterior part of the head our specimen fails to be of value in differentiating the two genera; in fact, the only means of decision is the discovery of a more perfect example of *Kritosaurus novajovius*. As far as the preserved parts are concerned I should have no hesitation in ascribing our species to either genus and as *Kritosaurus* has priority that generic name is used. Should further investigation show that the genera are distinct, the greater resemblance to Lambe's type would necessitate the removal of our species to *Gryposaurus*.[2]

Lambe objects strongly and with very good reason to the use of *Trachodon* as a generic name and, consequently, to that of *Trachodontidae* as a family designation. He prefers to found the family on Leidy's genus *Hadrosaurus* as proposed by Cope in 1869, whereas *Trachodontidae* was introduced by Lydekker in 1888. The genus *Trachodon* was founded on a single mandibular tooth but *Hadrosaurus* rests on far more extensive material. Lambe, therefore, gives the following

[1]Bull. Am. Mus. Nat. Hist., Vol. XXVIII, Art. XXIV, 1910.

[2]After the examination of a photograph Mr. Brown has assured me that the specimen is undoubtedly an example of his genus.

classification of the family, enumerating the genera in which the structure of the head is fairly well known:

FAMILY HADROSAURIDAE

Sub-Family HADROSAURINAE

Gryposaurus, *Lambe*, Belly River
Edmontosaurus, *Lambe*, Edmonton
Kritosaurus, *Brown*, Uncertain horizon
Claosaurus, *Marsh*, Lance
Diclonius, *Cope*, Lance

Sub-Family SAUROLOPHINAE

Stephanosaurus, *Lambe*, Belly River
Prosaurolophus, *Brown*, Belly River
Corythosaurus, *Brown*, Belly River
Saurolophus, *Brown*, Edmonton
Cheneosaurus, *Lambe*, Edmonton

It will be observed that Lambe does not admit the identity of *Gryposaurus* and *Kritosaurus* and that "*Trachodon*" with all its derivatives is eliminated from the nomenclature. Despite Lambe's contention "*Trachodon*" has not been read out of the literature; in consequence, avoiding all contention, the systematic position of our species may be indicated as follows:

Order Dinosauria
Sub-order Predentata
Family Trachodontidae *or* Hadrosauridae
Sub-family Trachodontinae *or* Hadrosaurinae
Genus Kritosaurus *or* Gryposaurus

It is worthy of note that *Kritosaurus (Gryposaurus)* is the only genus of the *Trachodontinae*, i.e., crestless trachodonts with non-footed ischia, occurring in a horizon of the Upper Cretaceous as low as the Belly River.

Kritosaurus incurvimanus is a typical crestless trachodont with non-footed ischia. It is distinguished by the deep and narrow head with a probable median nasal protuberance, by peculiarities of the integument, by the presence of distinct dermal callosities along the median line of the back, by the possession of two wedge-shaped phalanges in the manus and of four phalanges in the fifth digit, and by peculiarities of the mandibular teeth. It is distinguished from *Kritosaurus (Gryposaurus) notabilis* by a slight difference in the shape of the orbit, a more anterior position of the nasal prominence, a greater separation of the jugal and quadrate by the quad-

[1]Ottawa Naturalist, Vol. XXI, No. 11, p. 138, 1918.

rato-jugal, the failure of an emargination on the anterior edge of the orbit, and by the generally smaller size.

The head is approximately 2 feet 3 inches in length; the thirteen cervical vertebrae measure 3 feet 6 inches; the sixteen dorsal vertebrae extend 5 feet 4 inches; the nine sacral vertebrae account for 2 feet 6 inches, and the seventeen caudals (all that are preserved) for 4 feet 2 inches. The total length was probably about 27 feet. The drawing (Plate I) shows the various parts of the skeleton in the position in which they lay in the quarry except for necessary adjustment in the case of some of the bones of the hind feet. No restoration has been attempted beyond the dotting in of bones where required to show the association of others. The photograph (Plate II) shows the skeleton as mounted. The position of the head has been altered, the pose of the limbs slightly changed, and a few missing phalanges of the pes restored.

The relationships of the species as indicated by the head have already been briefly reviewed. The skeleton shows closer affinities with *Claosaurus annectens* than with any other crestless trachodont of which the body has been described. The skeleton of *Claosaurus annectens*, mounted in the United States National Museum, measures 26 feet 3 inches and the estimated length of our specimen is 27 feet. It may be concluded, therefore, that the animals are of essentially the same size. The fore limb, however, is relatively longer than in *C. annectens*, the humerus, and radius and ulna being one-fourth greater. In the hind limb the femur is about equal in both species but the tibia and fibula are 1.07 the length of the corresponding bones of *C. annectens*. The same relationship is observed in the third metatarsal. Despite the greater length of the limbs both the pectoral and pelvic girdles are lighter in our species. The scapula, ilium, and ischium are distinctly shorter but the prepubis is longer, narrower, and of very different shape.

Detailed Description

Head

Plates III and IV

The left or exposed side of the head had lost by erosion both temporal arcades, the quadrate, the whole of the anterior end, and most of the squamosal and pterygoid. The quadratojugal was found unimpaired lying in the matrix of the orbit, and several fragments of the jugal, maxilla, and dentary were also recovered.

The softening of the rock on the upper or left side has made possible the working out of the anatomy of the cranium proper which would have been difficult or even impossible in the extremely hard matrix in which the under side was embedded.

The narrow and deep character of the head is indicated in the table of measurements at the close of this section. Making allowance for the smaller size it will be observed that the proportions are very similar to those of *Gryposaurus notabilis* which are introduced for comparison.

The *nasals* (N) meet on the median line in a clearly marked straight suture; posteriorly they meet the frontals in a more irregular overlapping suture with a marked posterior prong medially. They are bounded laterally by the prefrontals and infero-laterally by the premaxillaries but they do not meet the lachrymals. The premaxillary overlaps the nasal which extends to some distance below the suture.

The superior margin shows a slight concavity from the frontal suture forwards with only the suspicion of an upward tendency at the most anterior part preserved (135 mm. on the median line from the suture with the frontal). This point is a little in advance of the anterior end of the lachrymal. In *Gryposaurus notabilis* a vertical line in a similar position would cut the nasal prominence rather in front of than behind its maximum height. There can be no doubt that if our specimen possessed a nasal prominence it was situated far in advance of the position occupied by this determinative

feature in *G. notabilis*. It is chiefly on this account that the present species is regarded as distinct.

On the lateral aspect of the nasal, 70 mm. in front of the suture with the prefrontal and 45 mm. below the superior margin, there is a small foramen directed inwards, upwards, and backwards. Five millimetres above this opening there is a smaller and less conspicuous foramen.

The *lachrymal* (L) is a small bone forming about half of the anterior border of the orbit; it is bounded above by the prefrontal, supero-anteriorly by the premaxillary, below for 70 mm. by the jugal posteriorly and for 30 mm. by the maxillary anteriorly.

The *premaxillary* (Pm) is represented only by its posterior end which lies between the lachrymal and the nasal with a broadly overlapping suture on the latter bone.

The *prefrontal* (Prf) forms the antero-superior part of the orbital rim; it is separated from the postfrontal by a slight supraorbital notch. Intero-laterally it is in clear sutural union with the frontal and the nasal; inferiorly it meets the lachrymal which it seems to overlap. At the superior anterior angle of the orbit there is a slight groove on the external aspect of the bone. Below this groove and 15 mm. above the suture with the lachrymal there is a very small projection towards the orbit below which is a slight concavity in the orbital rim. This may represent, in a negligible manner, the distinct emargination on which Lambe places great stress in his description of *Gryposaurus notabilis*.

The *frontal* (F) meets its fellow in a slightly sinuous suture on the median line. Posteriorly it is bounded by the parietal to a point almost half way across the supratemporal fossa; here it meets the postfrontal, the suture with which runs forward to the supraorbital notch. The frontal, therefore, is excluded from the orbital rim except at the very base of the notch. There is no indication of a small supraorbital in this notch as suspected by Lambe in the case of *G. notabilis*. From the notch to the fronto-nasal suture the frontal is bounded laterally by the prefrontal. The superior aspect is slightly concave.

The *postfrontal* (Pf) forms the supero-lateral margin of the head from the supraorbital notch to within a short distance of the posterior end of the upper temporal arcade. Internally it meets the parietal in a very irregular suture which passes downwards at about the middle of the anterior border of the supratemporal fossa. The suture with the frontal passes irregularly forwards and outwards to the supra-orbital notch. Nearly two-thirds of the postorbital bar is formed by a descending process of this bone which is much stouter than the ascending process from the jugal. There is a distinct concavity on the outer aspect of this process superiorly. The suture with the squamosal is uncertain but it seems to cross the arcade irregularly on the superior aspect and to run sharply forwards and downwards on the lateral aspect as in *Gryposaurus notabilis*.

The *parietal* (Pa) meets its fellow in a very narrow and sharp crest between the supratemporal fossae. On the upper surface of the skull it is in sutural union only with the frontal; laterally it joins the postfrontal, the suture passing irregularly downwards near the middle of the anterior border of the supratemporal fossa. Inferiorly the parietal is bounded by the orbitosphenoid anteriorly and by the prootic (?) posteriorly. The suture with the squamosal seems to be almost on the median line causing the parietals to terminate posteriorly in a narrow point. The sharp median crest of the united parietals which separates the two supratemporal fossae bifurcates anteriorly and each branch curves outwards around the intero-anterior angle of the fossa thus forming a clearly marked triangular area with concave sides at the junction of the parietals with the frontals.

The *squamosal* (S) meets the postfrontal as described above and forms the whole of the posterior rim of the supra-temporal fossa. Posteriorly the bone descends abruptly into the nuchal depression where it seems to terminate against a small supraoccipital. From the outer side of the nuchal depression the posterior margin ranges upwards and forwards and then passes downwards to the extremity of the para-occipital process of which it forms the external and anterior

faces. The suture with the exoccipital which forms the inner side of this process is very clearly marked by a distinct depression. Laterally there is a deep cotylus for the head of the quadrate in front of which a spur extends downwards a distance of 30 mm. from the rim above the cotylus. From the end of this spur to the suture with the postfrontal the inferior margin of the squamosal is deeply concave and forms the upper posterior rim of the postorbital fossa. Externally and above this rim the squamosal is concave and in the concavity lies a forwardly directed process which is in close contact with but apparently not united to the outer surface of the squamosal.

The *quadrate* (Q) is a very long, shaft-like bone with an anterior wing for union with the pterygoid. It is slightly curved upwards and backwards and is excavated on the antero-lateral margin for union with the quadrato-jugal. The lower end is evenly rounded for articulation with the mandible.

FIG. 1—Left quadrato-jugal. One half natural size.

The *quadrato-jugal* (Qj) (Fig. 1) is a small, triangular bone terminating above in a thin acute angle: it is set into a distinct excavation on the antero-external side of the quadrate and is overlapped anteriorly by the jugal which is almost if not entirely out of contact with the quadrate. In this respect the present species more closely resembles *Kritosaurus novajovius* than *Gryposaurus notabilis*. The external surface shows radiating lines of growth; the anterior edge is very thin; the posterior edge is thicker; the interior posterior surface is hollowed where it fits into the depression in the quadrate.

The *jugal* (J) is a long curved bone with a marked downward turn over the coronoid process of the mandible and with a slender ascending process which forms the lower part of the postorbital bar. It broadly overlaps the quadrato-

jugal and almost touches the quadrate superiorly. Anteriorly the bone meets the lachrymal above and the maxilla below; it seems to have a marked outward inflection at the former suture, but this may be due to pressure.

The *maxillary* (Mx) is a deep and massive bone strongly incurved superiorly, particularly in the posterior part: this incurving of the alveolar margin is so great that it lies 80 mm. internal to the outer face of the jugal. The usual prominent ridge runs backwards on the external face from the lower edge of the suture with the jugal. In front of this suture the bone greatly increases in height and is in sutural union with the lachrymal above. The relationship with the premaxillary is not shown.

Close in front of the lower part of the suture with the jugal is a prominent, backwardly directed foramen; 50 mm. in front of this and a little higher up is another (not shown in the plate).

Nine maxillary teeth appear in a distance of 67 mm. Their structure is not well shown but they appear to be of the ordinary carinate type. The dentigerous groove is at least 55 mm. deep but its length can not be ascertained owing to the loss of the anterior part.

Internally the maxillary is in contact with the pterygoid but the exact relationships are difficult to ascertain.

The *basioccipital* (Boc) and *exoccipital* (Eco) are so fused that a sutural union can not be observed. That the latter bone contributes to the formation of the occipital condyle can not be stated, but that it bounds the foramen magnum laterally is almost certain.

The occipital condyle is broad and slightly convex posteriorly on the horizontal line; vertically it is not very convex on the posterior aspect but turns sharply downwards and forwards at the postero-inferior angle. The under surface is broadly convex laterally; antero-posteriorly it is slightly convex in the rear and concave towards the front. The main articular surface looks strongly downwards.

Viewed from the rear the condyle has a trifid appearance, as on either side, above and outwards from the main portion of the condyle, is a pronounced process with articular surface

directed outwards and backwards. Above these structures the bone has a pillar-like appearance for a short distance. The inner surface of the pillar is continuous with the inner and upper surfaces of the articular tuberosities mentioned above and continues evenly inwards and forwards to form the lower half of the lateral boundary of the escutcheon-shaped foramen magnum.

Above the pillar-like portion the bone may be resolved into two ascending, expanded elements which are continuous with each other. The inner of these rises from the pillar, passes forwards and upwards, and then strongly upwards and backwards terminating in a sharp ridge above which is a suture, in all probability with the supraoccipital. This section forms the upper half of the border of the foramen magnum, above and outward from which the bone is slightly but distinctly concave.

The outer ascending section expands above the pillar-like part and turns outwards and downwards to form the postero-internal surface of the prominent paraoccipital process. Superiorly this part of the bone is greatly thickened and forms a prominence posterior to the squamosal from which it is separated on the superior aspect of the head by a conspicuous open suture.

The relationship of the basioccipital to the bones of the temporal region is very doubtful as no actual sutures can be seen, and the surface of the bones is abraded in places. The coalesced occipital bones are in contact with the prootic above and possibly with a lateral ascending process from the basisphenoid below.

Outwards from the anterior concave part of the under surface of the basioccipital is the usual well developed descending tubercle, the basioccipital tubercle (Boc. Tub.). On the lateral aspect of the bone above the tubercle is a small slit-like aperture, probably for the passage of an artery. Above and behind this is a sub-triangular foramen for a branch of the twelfth nerve. Behind this opening should be a foramen for the second branch but the condition of the bone prevents its recognition

In front of the basioccipital tubercle there is a pronounced depression running upwards and backwards and terminating at a foramen for nerves IX to XI. No actual suture is to be seen in this depression but it is suggested that it may represent the line of union between the basioccipital and an ascending process of the basisphenoid.

The *supraoccipital* is a small bone forming the floor of the pronounced nuchal notch; it is clearly separated from the thin ascending inner flange of the exoccipitals and it abuts laterally against the thickened upper part of the outer flange but no trace of a suture is to be observed. Anteriorly the bone is in contact with the squamosals and possibly touches the posterior thin edge of the united parietals in the midline.

The sutures of the *basisphenoid* are all uncertain and the union ventrally with the basioccipital is entirely obscured. The bone doubtless forms the usual basal plate from which lateral processes seem to ascend between the orbitosphenoid and the basioccipital. Presumably this process is in union superiorly with the prootic but the only indication of such union is a slight crease which runs downwards and backwards from the foramen of the fifth nerve. Latero-ventrally there is a stout rod-like process extending downwards and outwards to the pterygoid; this is the basipterygoid process of the basisphenoid (b.p.). Viewed from the rear this process maintains its rod-like appearance. In the midline postero-ventrally there is a median rod-like process extending downwards and backwards to the pterygoids.

The *prootic* shows a distinct suture above with the parietal and anteriorly with the upper part of the orbitosphenoid. The latter suture can be traced indistinctly to the large foramen of the fifth nerve below which it is lost. Posterior to this opening the bone has the appearance of a roughened bar between the foramina of nerve V and nerves IX-XI. The fenestra ovalis is a larger and the foramen of the seventh nerve a smaller opening in this bar. No epiotic or opisthotic can be distinguished and a union ventrally with the ascending process of the basisphenoid is conjectural only.

The *orbitosphenoid* (O.sp) is a large and irregular element suturally united above with the parietal and postfrontal: it forms the inferior part of the anterior boundary of the supratemporal fossa and extends downwards in the rear of the orbit. A sharp plication of this downward extension forms the posterior border of the orbit in this region. There is a broad superior extension anteriorly which is in union with the prefrontal above and with the presphenoid in front. The inferior sutures are all uncertain. In Plate III a suture with the parasphenoid is faintly indicated but this can not be regarded as at all certain. From the foramen of the fifth nerve downwards and forwards is a distinct parting with the upper portion overhanging the lower: this is possibly, but not certainly, a suture with the ascending process of the basisphenoid.

The foramen of the fifth nerve is a large opening on the posterior border of the bone: it is continued forward as a distinct groove on the outer surface. The foramen of the fourth nerve enters the cranium from the rear of the orbit nearly on a level with the above groove. Immediately below, at the union with the parasphenoid, is a larger foramen for the third nerve.

The arrangement of the bones in the anterior part of the sphenoidal region seems to differ in several respects from that of other members of the family which have been figured. Extending forward from the foramen of the third nerve is a distinct vacuity which separates the parasphenoid from the orbitosphenoid and the presphenoid. Above this vacuity, on the intero-inferior margin of the forward extension of the orbitosphenoid, is a fairly large foramen, probably for the second nerve. Above this opening is a narrow longitudinal groove passing posteriorly into a small foramen, probably for a blood vessel.

The *parasphenoid* (Pa.sp.) extends forward from the basipterygoid process of the basisphenoid; its inferior margin is slightly concave as is also its outer face. Anteriorly the bone divides into a long inferior and a shorter superior process. Above, as already stated, it is separated by a

distinct vacuity from the presphenoid and orbitosphenoid for the anterior three-fourths of its length. Posteriorly it seems to be in contact with the orbitosphenoid but the suture is practically obliterated.

The *presphenoid* (Pre.sp.) is a small bone connected with the anterior wing of the orbitosphenoid by an overlapping suture; its antero-superior edge meets the frontal. The inferior margin is tongue-shaped and is separated from the parasphenoid by the vacuity already referred to.

The *pterygoid* (Pt.) is a very irregularly shaped bone consisting essentially of four parts—a posterior horizontal expansion, a posterior vertical expansion, an anterior palatal portion connected with the maxillary, and a descending process. The horizontal posterior expansion is quite thin, meets its fellow in the midline, and its posterior free margin trends outwards and backwards to a suture with the quadrate. Between the central and lateral inferior processes of the basisphenoid it arches upwards but it sinks into a depression at the point of union with the lateral process (basipterygoid process).

In front of the basipterygoid process the posterior vertical wing rises as a very thin sheet which extends backwards and outwards overlapping internally the forwardly directed wing of the quadrate.

The anterior or palatal extension can not be differentiated as an ectopterygoid and it is so closely applied to the maxillary that a sutural line can not be clearly seen. This palatal portion is rounded superiorly at its posterior end; anteriorly it is inflected forwards, upwards, and inwards, and meets, or almost meets, the corresponding bone of the other side.

Inferiorly and in line with the posterior ascending process is a descending process which seems to overlap the posterior end of the maxillary, and with the lateral part of the horizontal plate to form a large concavity directed forwards at the upper angle of the posterior end of the maxillary. This part is badly broken and no sutures can be made out with certainty.

The *mandible* is very robust and deep and is strongly inflected towards the alveolar border which is 80 mm. internal to the outer surface of the strong coronoid process. The preserved portion shows that the dentary was probably deflected anteriorly. Its suture with the angular follows the inferior margin of the mandible and can scarcely be seen in a lateral view. The suture of the dentary with the surangular sweeps downwards and backwards from the posterior margin of the coronoid to the inferior edge of the mandible. The suture of the surangular and angular follows the inferior margin to the posterior end. The articular turns in behind the foot of the quadrate; its sutures are not observable.

The *mandibular teeth* (Plate IV) are not well exposed but they seem to be arranged in three or four vertical rows with the grinding surface highly inclined upwards and inwards. The total number of rows is, of course, indeterminable owing to the loss of the anterior part of the mandible; seven rows occur in a distance of 55 mm.

A fragment of the mandible shows well preserved teeth but they are all split vertically except one of the innermost series which must serve as a type tooth for the species. This tooth is 18 mm. long and 5.5 mm. wide at midlength; it tapers downwards to a width of 2.5 mm. at the root. Upwards from the point of maximum diameter the tooth contracts gradually to a fairly sharp point, the actual termination being slightly broken. The inner enamelled surface shows the usual carina which is quite low. Between the carina and the lateral margins, both above and below midlength, is a gently concave depression rising to an exsert edge. Above the middle, this raised edge carries eight small tubercles which are fairly evenly spaced except at the bottom where the lower two are more closely set. These tubercles look distinctly upwards.

In shape the tooth resembles that figured by Brown for *Kritosaurus novajovius*; it is, however, much smaller and the papillae are larger, more clearly defined, and much less numerous. Moreover, the lateral margin is slightly raised

making the space between it and the carina concave and not flat as in Brown's species. With regard to the teeth of *Gryposaurus notabilis* Lambe says: "The teeth are of the usual trachodont type and are in from two to three rows in the grinding surface of the lower jaw. A satisfactory examination of the inner enamelled surface of the lower teeth has not been possible, but in two of the teeth seen from the inner side the margin appears to be smooth or nearly so."[1]

In cross section the teeth show an exceedingly fine radial and concentric structure like that presented by a piece of fossil wood. Towards the roots the teeth seem to have been hollow; they are embedded in a granular carbonaceous layer about 1.5 mm. in thickness.

COMPARATIVE MEASUREMENTS OF THE HEAD

	Gryposaurus notabilis		Kritosaurus incurvimanus	
	Ft.	In.	Ft.	In.
Height of head from lower edge of dentary to highest point of squamosal	1	8	1	4½ (415 mm.)
Breadth between upper rim of orbits		9⅜		7 (178 mm.)
Height of quadrate	1	4¾	1	1 9/16 (345 mm.)
Length of supratemporal fossa		6		5½ (140 mm.)
Width of supratemporal fossa		4		2⅞ (73 mm.)
Height (oblique) of lateral temporal fossa		11¾		8 13/16 (225 mm.)
Width (horizontal) of lateral temporal fossa		5½		4⅞ (118 mm.)
Height (oblique) of orbital opening		8⅜		6 5/16 (160 mm.)
Width (horizontal) of orbital opening		5		4 5/16 (120 mm.)
Width of head at anterior of lachrymals				3 15/16 (100 mm.)

Nasal—	
Width at suture with frontal	50 mm.
Minimum width to prefrontal suture	40 mm.
Depth (vertical) to the angle at the junction of premaxilla, lachrymal, and prefrontal	56 mm.
Width of head across the two nasals, 120 mm. in front of orbit	60 mm.
Lachrymal—	
Width	45 mm.
Length	100 mm.
Suture with prefrontal	45 mm.
Suture with premaxilla	70 mm.

[1]Ottawa Naturalist, Vol. XXVII, No. 11, p. 148.

Prefrontal—	
Length	142 mm.
Width on suture with lachrymal	45 mm.
Width above orbit	38 mm.
Frontal—	
Length on midline	70 mm.
Width at supraorbital notch	80 mm.
Postfrontal—	
Length	175 mm.
Bottom of descending process to top	113 mm.
Horizontal width of upper temporal arcade	22 mm.
Vertical width of upper temporal arcade	25 mm.
Outer edge of upper arcade to interparietal suture	73 mm.
Parietal—	
Length on median line of head	140 mm.
Width at suture with frontal	35 mm.
Width, interparietal to orbitosphenoid suture	55 mm.
Squamosal—	
Width from suture with parietal to rim above cotylus for quadrate	118 mm.
Posterior rim of supratemporal fossa to suture with exoccipital	60 mm.
Rim above cotylus to end of paraoccipital process	125 mm.
Quadrate—	
Length	345 mm.
Diameter of shaft above quadrato-jugal	55 mm.
Jugal—	
Total length	300 mm.
Width below orbit	55 mm.
Width below postorbital fossa	49 mm.
Inferior edge to top of ascending process	150 mm.
Basioccipital and exoccipital—	
Base of condyle (vertical) to supraoccipital suture	140 mm.
Median line (horizontal) to end of paraoccipital process	130 mm.
Median descending process of basisphenoid to posterior extremity of condyle (horizontal)	100 mm.
Base of basioccipital tubercle to Nerve IX-XI	68 mm.
Height of foramen magnum	50 mm.
Width of foramen magnum	34 mm.
Width across trifid part of condyle	77 mm.
Width of main part of condyle	65 mm.
Supraoccipital—	
Length	37 mm.
Width	72 mm.
Orbitosphenoid—	
Total length	115 mm.
Height measured vertically	85 mm.
Edge of orbital fold to posterior of foramen of fifth nerve	53 mm.

Parasphenoid—	
Length from basipterygoid process to anterior end	125 mm.
Pterygoid—	
Basal posterior sheet; midline to extreme point of suture with quadrate	125 mm.
Basipterygoid process to anterior end of palatal portion	165 mm.
Quadrato-jugal—	
Total length	130 mm.
Total width	80 mm.
Maximum width of part not overlapped by jugal	40 mm.
Maximum thickness	14 mm.
Mandible—	
Height of dentary, measured vertically from inferior to alveolar margin	102 mm.
Extreme end of articular to front edge of coronoid process	218 mm.

VERTEBRAL COLUMN

The vertebral column is divisible into a cervical region of thirteen vertebrae, a dorsal of sixteen, a sacral of nine, and a caudal of undetermined number of which seventeen are preserved.

The *atlas* (Fig. 2) consists of four pieces—hypocentrum, odontoid, and two halves of the neural arch. The hypocentrum (intercentrum) is a rather stout, transversely curved, ventral bone about 90 mm. wide. The anterior ventral edge is rather sharp but the upper edge is excavated for the odontoid. The thickness (ant-post.) is about 30 mm. The posterior face fits, in a sinuous manner, into a transverse ventral groove on the anterior face of the axis; this groove is deeper towards its upper centre.

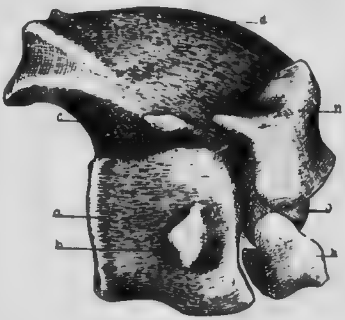


FIG. 2—Atlas and axis, right lateral view. One fourth natural size.
a, *centrum of axis*; b, *parapophysis of axis*; c, *diapophysis of axis*; d, *neural spine of axis*; h, *hypocentrum of atlas*; o, *odontoid*; n, *neural arch of atlas.*

The odontoid fits into the curved upper margin of the hypocentrum; it measures 65 mm. transversely and rather less vertically. The anterior face shows a rounded ventral margin but the bone is

distinctly concave supero-anteriorly. The posterior face is not well shown but it seems to be slightly convex and to abut against a forwardly directed convexity situated on the anterior face of the axis above the groove for the hypocentrum.

The neural arches surround the superior part of the odontoid and almost touch the hypocentrum. Each arch measures 92 mm. vertically. The main basal part is 40 mm. long and 20 mm. thick near the lateral line of the column; it slopes forward to a rather sharp edge and upwards to the maximum height of the spine which is well forward. The superior edge slopes down, back, and slightly outwards, 71 mm., to a pronounced point, the postzygopophysis, which overlaps the stout prezygopophysis of the axis. From this point the posterior margin is slightly concave and extends outwards 40 mm. forming a stout diapophysis 30 mm. long antero-posteriorly. The two halves of the arch touch at the summit but diverge posteriorly; it is impossible to say whether or not there is a real union at the point of contact.

The centrum of the *axis* (Fig. 2) is 70 mm. long on the lateral line and 78 mm. long on the ventral line: it is strongly opisthocoelous but the anterior face is relatively flat with a transverse inferior groove for the hypocentrum of the atlas; this groove is deepest in the centre but above the depression the face of the centrum extends forward in a convexity which seems to be in contact with the odontoid. Rather low, and well forward on the lateral aspect of the centrum, is a large blunt process or parapophysis.

The neural arch is very large and extends into a plate-like spine 125 mm. long postero-anteriorly reaching forward between the arches of the atlas almost to the summit of the spine. A slender diapophysis occurs in the usual position; from its base a strong ridge runs backwards and upwards on the plate-like spine and terminates in a pronounced point in the supero-latero-posterior position. This point is 50 mm. from the posterior end of the spine proper. Thirty-eight millimetres below the point is a well developed postzygo-

pophysial facette which strongly overlaps the prezygopophysis of the third vertebra. The total height of centrum and spine is 160 mm.

The remaining cervical vertebrae (Figs. 3 and 4) do not differ from one another except in a gradually increasing size posteriorly. The third vertebra is at least 85 mm. long; it is strongly opisthocoelous and correspondingly convex anteriorly, indicating much latitude of movement. There is a lateral foramen in the centrum. The parapophysis is smaller and higher up than that of the axis. The prezygopophysis is stout and outwardly directed; the postzygopophysis is very robust and is the most conspicuous part of the arch; it is directed outwards, upwards, and backwards to a length of 80 mm. and carries a wide articular facette. The neural spine is very small, not over 18 mm. high.

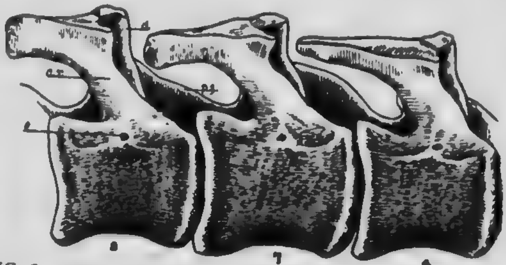


FIG. 3—Sixth, seventh, and eighth cervical vertebrae, viewed from below and slightly from the right; left side not shown. One fourth natural size.

d, *diapophysis*; pz, *postzygopophysis*; c.r., *cervical rib*; f, *foramen*.

The remaining cervical vertebrae resemble the third except for some details of measurement. The centra gradually increase in length from 85 mm. in the third to 100 mm. in the thirteenth. The diapophyses increase from 40 mm. in the third to 140 mm. in the thirteenth, measured

FIG. 4—Sixth, seventh, and eighth cervical vertebrae, viewed from the right. One fourth natural size.

n.s., *neural spine*; pz, *postzygopophysis*; d, *diapophysis*; c.r., *cervical rib*; p, *capitular branch of rib fused with parapophysis*; f, *foramen*.

in a slightly oblique direction from the hollow in the centrum between the parapophysis and the diapophysis. The neural spines are pointed and directed strongly backwards; they increase in length from 18 mm. in the third to 50 mm. in the thirteenth vertebra.

The postzygopophyses increase from 80 mm. in the third to 120 mm. in the ninth vertebra and then gradually decrease to a length of only 75 mm. in the thirteenth vertebra. The measurement is from the lower posterior angle of the neural spine to the extremity of the process. In the posterior cervical region, where the curvature of the neck is greatest, the postzygopophyses are pushed down so far that they appear on the ventral side with the articular facettes quite exposed.

The thirteenth cervical bears a much larger rib than the twelfth and on this account might be considered as a dorsal. On the other hand, the fourteenth vertebra bears a strong postzygopophysis like those of the cervicals, whereas that of the fifteenth is conspicuously different. The distinctly dorsal rib of the fourteenth prohibits the possibility of including it among the cervicals; therefore, the possession of a very large postzygopophysis can not be made the basis of division.

The *dorsal vertebrae* are sixteen in number. Owing to a parting along the base of the neural spines in removing the skeleton from the quarry, and to the necessity of leaving the matrix for the support of the ribs and muscles the characteristics of these vertebrae are only partly revealed. The centra increase in width and height but decrease in length; the sixteenth is 68 mm. long and appears to be amphiplatyan. The total height of this vertebra, from the base of the centrum to the top of the spine, is 438 mm.

The neural spine of the first dorsal is considerably larger than that of the last cervical. From a length of 90 mm. in the first the spines increase in length to 135 mm. in the second, 160 mm. in the third, 210 mm. in the eighth, and 230 mm. in the sixteenth vertebra. The first four spines, like those of the posterior cervicals, are pointed and directed backwards; the fifth and sixth are less pointed but still with

a backward inclination; the seventh is more erect, broader, and with a square top. The remaining dorsal spines are similar to the seventh and have an average width of about 80 mm.

The diapophyses of the dorsal vertebrae are very stout processes directed outwards and slightly upwards and with a strong backward inclination in accord with the direction of the neural spines. The first and second are relatively slender, quadrangular in cross section, and about 150 mm. long measured from the base of the neural spine. As the centra are covered these processes can not be measured in the same manner as those of the cervicals. The thickness (ant-post.) is about 30 mm. The third diapophysis has the anterior edge drawn out to a sharp flange near the point of origin and this feature becomes more pronounced in the succeeding vertebrae. Similarly the posterior edge of the process gradually assumes a like character, the flange merging into a backwardly directed extension at the base of the neural spine. These extensions function as pre- and postzygopophyses respectively, the former overlapping the latter. The diapophyses decrease in length from 150 mm. in the first to 110 mm. in the last dorsal vertebra.

The *sacrum* is composed of nine fused vertebrae followed by a tenth which presents some features common to the other sacrals. Its transverse process is remarkably like that of the ninth sacral and sharply different from that of the first of the caudal series; I propose to regard this vertebra as a sacro-caudal and to include it in the caudal region. The first sacral centrum is firmly fused to the second and is much longer than the last dorsal, but it seems to bear no transverse process. On this account some authors would regard it as a dorso-sacral.

The first four sacral centra are about 80 mm. long; the fifth, sixth, and seventh are not observable; the last two are somewhat shorter being about 70 mm. in length.

The diapophyses of the sacral vertebrae, viewed from the dorsal aspect, seem slighter than those of the posterior dorsals; the anterior ones are directed forwards but the

last two are bent backwards, perhaps by pressure. Near the point of origin the anterior edge is inclined downwards and the posterior edge upwards resulting in ill defined pre- and postzygopophyses the former of which seem to overlap the latter. The postzygopophysis of the first vertebra is more pronounced than those of the succeeding sacrals, but the arrangement of the articular surfaces, if such exist, is not well shown. The first three diapophyses are close together (30-40 mm. interval); the fourth to seventh are about 70 mm. apart; the eighth and ninth are bent backward and crowded together. The extremities of the first four diapophyses are hidden under the anterior ramus of the ilium which extends 250 mm. in advance of the first. The fifth to ninth come in contact with the superior margin of the posterior ramus of the ilium. The height of the seventh diapophysis, measured from the base of the neural spine, is 160 mm.

The first four neural spines of the sacrum are curved strongly backwards as they spring from the arch but assume a direction nearly at right angles to the column at their extremities. The blade is broader than those of the neighbouring dorsals, averaging about 90 mm. The length along the median line is about 280 mm. The posterior edge of the curved part of each of these spines is inclined outwards and is continuous with the similarly inclined posterior edge of the diapophysis; this results in an overlapping proximally of the posterior by the anterior spine.

The remaining neural spines of the sacral region are less curved, do not overlap distinctly, and are narrower in the blade, not exceeding 80 mm. as in the case of the posterior dorsals.

Provisionally the structures arising from the sacral centra for the support of the pelvis will be called *parapophyses* (*vide postea*). As already stated the first sacral bears no such structure; that of the second rises as a broad plate at the extreme anterior edge of the centrum where it is continuous with the lateral face of the first centrum. This process extends back, out, and down, narrowing towards the centre and expanding distally; it seems to be quite separate from he diapophysis, but this can not be stated with certainty.

The corresponding structure of the third sacral is quite different as it assumes the form of a vertical plate at the anterior edge of the centrum, and is, apparently, in contact with the diapophysis throughout its length. These two parapophyses unite ventro-laterally and seem to be attached to the acetabular border of the pubis.

The corresponding structures of the fourth, fifth, and sixth sacral vertebrae can not be seen but they are probably similar to that of the third. The seventh vertebra bears a stout transverse plate, anteriorly placed, strongly inclined forwards, continuous with the anterior edge of the diapophysis, and attached to the postacetabular border of the ilium; it is about 90 mm. long. The parapophysis of the eighth sacral vertebra rises at the extreme anterior edge of the centrum as a vertical plate directed straight outwards. Its general position is slightly anterior to the diapophysis with which it is connected throughout its length; it expands distally and is attached to the upper inner side of the posterior ramus of the ilium, whereas the extremity of the diapophysis appears over the superior margin of that bone.

The ninth sacral vertebra has no distinct parapophysis but the diapophysis is stouter and more expanded than that of the succeeding sacro-caudal vertebra. Its anterior edge is drawn out ventrally and extends some distance down on the centrum, thus taking the place of the more distinct parapophyses of the anterior sacral vertebrae.

Whether these so-called parapophyses are to be considered as separate ossifications, and, therefore, as sacral ribs, is open to question, as the nature of the union with the diapophyses is in no case clearly revealed. The first parapophysis, that of the second sacral vertebra, is disconnected from the diapophysis and shows no sign of sutural union with the centrum with which it appears to be quite continuous. On the other hand, the corresponding structure of the sixth vertebra seems to have a very distinct sutural union with the centrum.

Seventeen *caudal vertebrae* are preserved (Fig. 5). The centra gradually decrease in length from 70 mm. to 55 mm.

and in height, measured from the ventral side of the base of the transverse process to the ventral anterior edge, from 105 mm. to 80 mm. The total height of the centra is not observable for the whole series, but the fifth is 130 mm. and the seventh about 85 mm. As the left side is buried in the matrix the width of the centra can not be measured; the tenth is estimated to be 110 mm. wide.

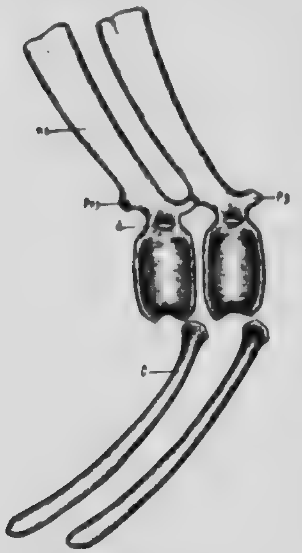


FIG. 5—Eleventh and twelfth caudal vertebrae. One eighth natural size.

n.s., *neural spine*; Poz, *postzygopophysis*; d. *transverse process*; Pz, *prezygopophysis*; c, *chevron*.

The transverse process of the first caudal vertebra, regarded as a sacro-caudal, is a stout structure 100 mm. long; it is arched dorsally, i.e., it at first ascends and then descends. The distal end is expanded and is 60 mm. wide antero-posteriorly; it touches the extreme posterior end of the ilium and almost touches the transverse process of the last sacral. On account of the resemblance of this process to that of the preceding vertebra and of its sharp differentiation from that of the next succeeding, the vertebra is regarded as a sacro-caudal.

The transverse processes of the remaining caudals are slender, curved, somewhat variable, spine-like structures flattened dorso-ventrally. They arise from the superior lateral angle of the centra, in the proximal vertebrae rather far forward, but in the distal vertebrae more towards the posterior. From a length of 90 mm. on the second caudal, these processes decrease gradually in length to a mere spur of five millimetres on the seventeenth.

The neural spines of the caudal vertebrae curve backwards with the concavity of the curve anterior. The length decreases from 300 mm. in the third to 230 mm. in the twelfth which is the last that can be measured with certainty. The

blade decreases in width from 60 mm. in the first to 50 mm. in the tenth.

A small postzygopophysis with an articular facette is overlapped by a somewhat stronger prezygopophysis; this is the opposite of the condition observed in the cervical and dorsal regions.

The chevrons are long and slender and seem to have two articular facettes on the slightly expanded head. In the region immediately below the head the diameter is somewhat reduced by the incurving of the posterior margin. The maximum width observed in the largest chevron is about 25 mm.

The first chevron, which occurs between the fifth and sixth caudal vertebrae, is 250 mm. long; the second and longest chevron measures 310 mm. The length gradually decreases to 256 mm. in the eleventh.

SHOULDER GIRDLE AND FORE LIMB

Except for some peculiarities in the structure of the coracoid and the manus, the bones of the fore limb are essentially the same as in other members of the group. The radius and ulna are shorter than the humerus as in *Claosaurus* and *Hadrosaurus*. Compared with *Claosaurus annectens*, an animal of equal size, the long bones of the fore limb are one-fourth greater, whereas the scapula is considerably shorter.

The *scapula* (Figs. 6 and 7) is a large bone with a broad, blade-like upper end and a greatly expanded and massive lower or articular end. The blade terminates above in a remarkably straight line and is not rounded as in most members of the group. The figure given in the preliminary description is incorrect in this respect; it was prepared from the imperfect left scapula and is herein corrected by the almost perfect outline of the right or under bone. The maximum width of the blade is not more than an inch below the extreme end. From this point downwards the blade gradually narrows and thickens reaching its minimum width about 300 mm. from the articular end.

The outer face of the bone is very flat in the upper third, but downwards it becomes more convex. The crest of the convexity ranges forward and becomes a decided prominence on the antero-external face of the lower part of the bone. About 90 mm. from the extreme lower end this crest falls off rapidly but rises again to a less extent over the articular surface for the coracoid. The margin of the crest where it begins to descend is deflected forward and has the appearance of an articular surface. It has been suggested that this surface was possibly in contact with a clavicle; on this account it will be called the clavicular crest.

FIG. 6—Left scapula, external view. One eighth natural size.

g.c., *glenoid cavity*; cor. *articular surface for coracoid.*

Between this crest and the postero-inferior margin of the bone where it swells out to form the glenoid cavity is a deep depression. The end of the clavicular crest and the swollen margin above the glenoid cavity are almost on a line at right angles to

FIG. 7—Left scapula; internal, proximal, and distal views. One eighth natural size.

g.c., *glenoid cavity*; cor. *articular surface for coracoid.*

the axis of the bone. This line is 90 to 100 mm. above the extreme end of the bone.

The interior face of the scapula is very flat to the point of minimum diameter below which is slopes up very gradually to the edges of the articular facettes.

The posterior edge of the bone is concave, thin, and sharp to within 80 or 90 mm. of the glenoid cavity where it rapidly expands. The anterior edge is convex and less sharp. Proximally it merges into the side of the clavicular crest which is slightly hollow anteriorly. The extreme lower anterior border ranges forward to form the edge of the facette for the coracoid.

The proximal view shows two distinct articular cavities; the anterior or coracoidal cavity is the larger and looks slightly inwards; the posterior or glenoid cavity is 90 to 100 mm. distal to the anterior and looks almost straight downward.

The *coracoid* (Fig. 8) is a small but fairly heavy bone, quite separate from the scapula with which it was in free articular union as shown by the smooth surfaces of the facettes of both bones. The coracoid may be resolved into two portions—an expanded proximal articular region, and a distal or anterior flange-like vertical extension. The proximal expanded portion bears a wide convex articular facette for the scapula and a concave facette for the humerus. The two facettes are separated by a deep foraminal notch as in *Iguanodon* and *Camptosaurus*. As the animal has every appearance of being adult it is doubtful if this notch ever became closed as in most tracho-

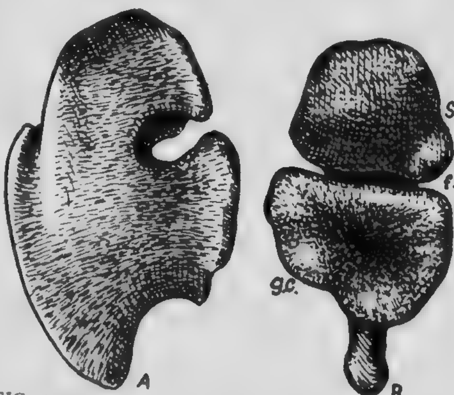


FIG. 8—Left coracoid; A, external view; B, articular view. One fourth natural size. g.c., *glenoid cavity*; f.n., *foraminal notch*; s.c., *scapular articulation*.

donts. The scapular facette looks rather more inward than that for the humerus.

The vertical expanded portion in front of the scapular facette decreases in diameter, at first gradually, and then more rapidly to a blunt rounded edge. In front of the glenoid facette the decrease in diameter is more rapid at first and then very gradual to an anterior edge which is thinner and longer than that in front of the scapular facette. These two parts of the anterior edge are not in line with each other, but the upper overlaps the lower externally thus giving the bone a twisted appearance when viewed from in front. The lower anterior edge shows a broad sweeping convex curve downwards to a prominent point, from which the inferior margin rises in a concave curve to the edge of the glenoid facette.

The inner face of the bone, in front of the scapular facette, is comparatively flat and slopes gradually forward to the upper anterior edge. Owing to the twisting already referred to, the upper end of the lower anterior edge forms a prominent point on the internal aspect of the bone.

The figure of the left coracoid which accompanies the preliminary description shows an emargination of the lower anterior edge; this must be due to injury as the better preserved right bone shows no such indentation.

The major limb bones of trachodont dinosaurs are so much alike that an opportunity for detailed comparison is necessary for an adequate description. The table of measurements at the end of this section is of more value than a detailed account of the bones.

The *humerus* (Fig. 9) was badly injured, particularly in the region of the radial crest, but its general characteristics as determined from both bones are fairly well revealed. The figure given by Lambe for the humerus of *Stephanosaurus marginatus* might serve to illustrate the present species except for some details of measurement.[1]

The humerus is a heavy bone, shaft-like in its lower third. Distally this shaft expands both laterally and antero-

[1]Contributions to Canadian Palaeontology, Vol. III, Geol. Sur. Can.

posteriorly into the inner and outer condyles, which are separated on both the anterior and posterior sides by distinct concavities. Both condylar expansions a.e conspicuously flattened externally; the planes of flattening are not parallel but inclined towards each other posteriorly. The articular surface of the inner condyle is sub-rhomboidal in outline and that of the outer sub-triangular.

FIG. 9—Left humerus; A, inner front view; B, outer rear view. One eighth natural size. h, *head*; oc, *outer condyle*; ic, *inner condyle*; r, *radial crest*; it, *inner tuberosity*; ot, *outer tuberosity*.

Above the constricted shaft the bone expands in two directions; antero-externally into the very prominent radial crest which continues upwards into the outer tuberosity, and posteriorly into a ridge, obliquel trans- verse to the which continues u into the inner tuber sity. On the anterior face these two expansions are separated by a slightly concave area and on the posterior face by an intermediate convexity which rapidly expands into the prominent head.

A proximal view shows the outer tuberosity as the lightest element, inclined slightly backwards and separated by a slight concavity from the head, which is robust and posteriorly situated. The inner tuberosity is intermediate in size between the head and the outer tuberosity and is not separated from the head by a marked depression.

The humerus in this species is longer than in *Trachodon mirabilis*, *Claosaurus annectens*, *Saurolophus*, or *Hypacrosaurus*; it is shorter than that of Lambe's *Stephanosaurus marginatus*.

The *radius* and *ulna* (Figs. 10, 11, and 12) show no striking features to distinguish them from the similar bones of other trachodonts. The relative length of these bones with respect to that of the humerus is regarded as a feature of generic value. In *Kritosaurus*, the ulna, over the olecranon process, is slightly shorter than the humerus and the radius is considerably shorter. This relationship is observed in *Trachodon* and *Hadrosaurus*, while in *Saurolophus* the bones are of equal length, and in *Hypacrosaurus* the radius is much the longer bone.

FIG. 10—Left radius and ulna, anterior view. One eighth natural size. u, *ulna*; r, *radius*; o, *olecranon process*; c', *larger carpal*; c'', *smaller carpal*.

The bones of the two sides agree closely in detail of measurement but there is considerable difference in the amount of curvature. The figures are based on the straighter bones of the left side but the more perfect radius of the right side has been used for some of the detail.

The *ulna* is a shaft-like bone with its minimum girth about 100 mm. above the lower end; the cross section at this point is sub-triangular and this outline becomes more pronounced as the bone expands distally to the articular surface. Above the minimum girth the bone expands in three directions; postero-internally into a thin and prominent flange, anteriorly into a less pronounced flange, and externally into a heavy ridge, or continuation of the shaft, which terminates above the proximal articular surface in the prominent olecranon process. The top of the radius fits nicely into the pronounced concavity between the first and second of these expansions. The proximal articular surface

is L-shaped, with the olecranon at the angle of the L. The distal articular surface is almost flat and triangular in outline. The flattened side of the bone is closely applied to a similar flat side of the radius. On the posterior side, above the distal end, there is a slight concavity extending some distance up the bone.

The *radius* is a simple, shaft-like bone, gently expanding towards the distal end and more abruptly towards the proximal end. The articular surface for the humerus is flat and ovoid in outline, while that of the distal end is sub-triangular and more rounded.

Two *carpals* were found in each limb. The larger is a sub-triangular bone with a greatest edge of about 40 mm. In the left foot it lies in the anterior position between the ulna and radius and is more closely associated with the latter which is rounded near its distal contact with the ulna to receive the carpal. In the right foot the bone is shifted to a posterior position.

The smaller carpal is a bone of doubtful shape, apparently irregularly discoidal to flattened ovoid. In both instances it was found, a short distance above the articular surface, in the hollow on the posterior face of the ulna. While the carpal could scarcely have occupied this position in life, the

FIG. 11—Left radius and ulna, posterior view. One fourth natural size.

similarity of position in the two legs seems to indicate that in each instance it was pushed a little upwards and that it actually occurred in the posterior position at the distal end of the ulna. The left bone is 28 mm. and the right only 12 mm. in diameter. All four carpal bones are imperfectly ossified as shown by the failure of distinct surfaces.

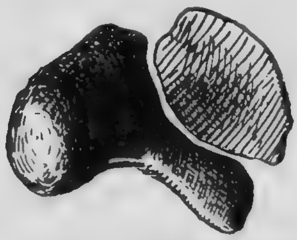


FIG. 12—Left radius and ulna, proximal view. One fourth natural size.

Both front feet were found with the palmar surface upwards. Of the left foot every bone was intact and practically in place; of the right foot the ungual of the second digit was about twelve inches out of position and the second phalanx of the same toe was not recovered. In both feet the second metacarpal, together with its phalanges, was drawn slightly upwards and its proximal end inflected inwards on the palmar side. In both cases, also, the fifth digit was flexed towards the palmar surface.

The *manus* of Trachodon has been the subject of some discussion. Brown, in 1912, reviewed the evidence and gave the following phalangeal formula:

Digit II with three phalanges, the third a hoof.
Digit III with three phalanges, the third a hoof.
Digit IV with three phalanges, no hoof.
Digit V with three phalanges, no hoof.[1]

In 1913 Lambe described the manus of a trachodont from the Edmonton formation in which the phalangeal formula was quite different from that given by Brown for the family:

Digit II with three phalanges, terminal presumably a hoof.
Digit III with three phalanges, terminal a hoof.
Digit IV with two phalanges, terminal a hoof.
Digit V with two phalanges, terminal a hoof.[2]

[1]The Osteology of the Manus in the family Trachodontidae, Barnum Brown, Bull. Am. Mus. Nat. Hist., Vol. XXXI, Art. 10.

[2]The Manus in a specimen of Trachodon from the Edmonton formation of Alberta, Lawrence M. Lambe, Ottawa Naturalist, Vol. XXVII, No. 2.

The manus of Kritosaurus (Plate V and Fig. 13) differs from both the above and shows the following phalangeal formula:

Digit II with three phalanges, the third a pointed hoof.
Digit III with three phalanges, the third a blunt hoof.
Digit IV with three phalanges, no hoof.
Digit V with four phalanges, the terminal a small ovoid bone.

The manus of *Kritosaurus* is comparatively small. The relative lengths of the different elements of the fore limb show the closest resemblance to the proportions of *Claosaurus annectens*. The humerus is 1.25 the length of that of *C. annectens*, and the radius is 1.26. The average of the third and fourth metacarpals, however, is only 1.04 that of *C. annectens*.

Metacarpal II is a fairly straight bone, slightly swollen in the middle and but little expanded at the articular ends. The external side is flattened, particularly at the distal end, and is closely applied to the internal side of metacarpal III, but the relationship is not so intimate as between metacarpals III and IV.[1]

Metacarpal III is a considerably longer and heavier bone with a slight twist, and is but little expanded towards the ends. The external side is flattened, particularly towards the ends, and is closely applied to metacarpal IV. Proximally this flattening causes the outer anterior angle to appear as a

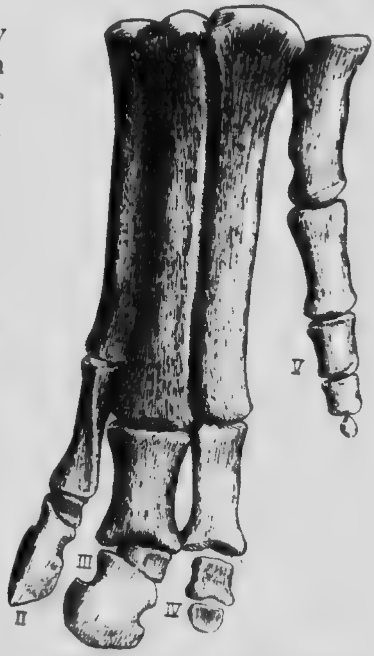


FIG. 13—Left manus. One fourth natural size.

[1]In all descriptions of the limb bones the terms *internal* and *external* are used with reference to the axis of the body, not of the limb.

sharp ridge. Internally, towards the palmar side, the bone is similarly flattened to fit against metacarpal II. Both proximally and distally the posterior side is elevated into a triangular keel. Both articular surfaces are slightly convex; the proximal is sub-triangular and the distal sub-quadrangular.

Metacarpal IV is of about the same length as metacarpal III and is flattened on its inner side for close connection with that bone. The proximal expansion is greater than in metacarpal III; the distal expansion is much lighter than the proximal and almost at right angles to it giving the bone a decided twist. Both articular surfaces are slightly convex.

Metacarpal V is a much smaller bone, divergent, and with no apparent connection with its neighbour. The proximal end is greatly expanded with an elliptical, concave articular surface. The distal end is smaller with an oblique and convex articular surface.

The phalanges of the first row (Plate V) are comparatively long bones; those of digits II, III, and IV are flat to slightly concave proximally; that of digit V is convex. The distal ends are expanded, with articular surfaces of much greater extent than those of the bones apposed to them. The bones of the second row of phalanges are very much smaller, that of digit V being much the longest. Phalanges II^2 and III^2 are small and distinctly triangular and must have caused an inward inflection of the hoofs: this has suggested the rather ill-formed specific name of *incurvimanus*. One triangular bone of this kind, similarly placed in digit II, is described by Lambe (*op. cit.*). Brown states that this phalanx in digits III and IV is slightly triangular. His figure shows that the bone in digit III is but slightly triangular with the edge inwards as in *Kritosaurus*. The triangular aspect is more pronounced in the case of digit IV but the thin edge is here on the outside. In both these cases the proximal articular face of the bone is as large as the apposed surface of the first phalanx; in *Kritosaurus* the bone is much reduced reaching only part way across the distal end of the first phalanx. The evidence seems to suggest

that the family was in process of acquiring rather than of losing hoofs. Phalanx IV^2 is a normal bone, but very short and with a remarkably small articular surface proximally. Had not this bone been found in place in both feet one would think that a phalanx were missing.

The third row of phalanges differs in each digit: II^3 is a somewhat inequilateral and pointed hoof; III^3 is a broader, inequilateral, shorter hoof; IV^3 is a small flattened bone with a distal surface strongly suggestive of still another phalanx or a nail; V^3 is very like V^2 except for its smaller size. A fourth phalanx appears only in the fifth digit; it is a very small sub-spherical to ovoid bone.

In the following tables of comparative measurements the species referred to are designated by Roman numerals as follows:

Kritosaurus incurvimanus	I
Trachodon mirabilis	II
Claosaurus annectens	III
Saurolophus osborni	IV
Corythosaurus casuarius	V
Stephanosaurus marginatus (Lambe's original figures)	VI
Hypacrosaurus altispinus	VII

In the case of *Kritosaurus* the figures given are the averages of the measurements of the bones of both sides.

COMPARATIVE MEASUREMENTS OF SHOULDER GIRDLE AND FORE LIMBS

	I	II	III	IV	V	VI	VII
Scapula—	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Length	776	900	810	970	890		
Maximum width of blade	189	220	200	230	200		
Minimum width of blade	120						
Maximum width at articular end	214						
Thickness from clavicular crest to inner face	103						
Length of scapular portion of glenoid cavity	110						
Width of same	64						
Facette for coracoid, length	80						
Facette for coracoid, width	60						

COMPARATIVE MEASUREMENTS OF SHOULDER GIRDLE AND FORE LIMBS—*Cont.*

	I	II	III	IV	V	VI	VII
	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Scapula—							
Height of clavicular crest from outer face of bone	67						
Coracoid—							
Antero-inferior point to upper edge of scapular facette	200	215					
Antero-inferior point to lower edge of glenoid facette	73						
Width of scapular facette parallel to foraminal notch	80						
Height of scapular facette at right angles to notch	65						
Depth of notch from inferior edge of scapular facette	35						
Width of glenoid facette parallel to notch	95						
Height of glenoid facette at right angles to notch	78						
Thickness of lower anterior expansion	22						
Thickness of upper anterior expansions	38						
Thickness in front of notch	52						
Humerus—							
Total length	630	610	501	500		683	580
Breadth at lower end of radial crest	170					165	
Circumference of shaft	214	255				265	
Breadth across head and outer tuberosity	138					140	
Breadth across head and inner tuberosity	130					130	
Breadth across inner and outer tuberosities	160					145	
Breadth of inner condyle (ant. post.)	82					80	
Breadth of outer condyle (ant. post.)	80					100	
Transverse width of inner condyle	50	100	110	85			
Transverse width of outer condyle	52						
Thickness of bone between the condyles	28						
Thickness of head	78						

COMPARATIVE MEASUREMENTS OF SHOULDER GIRDLE AND FORE LIMBS—*Cont.*

	I	II	III	IV	V	VI	VII
Humerus.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Thickness of inner tuberosity.....	41						
Thickness of outer tuberosity.....	31						
Ulna—							
Length over olecranon process....	610	680	500	630		708	750
Length between articular ends....	574						
Circumference of shaft...........	158	190	170				
Greatest width across coronoid process.....................	104					145	
Greatest width of antero-posterior expansion.....................	75					94	
Greatest diameter of distal end....	79					74	
Least diameter of distal end......	53					57	
Radius—							
Total length....................	555	620	440	600		632	700
Circumference at middle..........	136	175	120			155	
Thickness of proximal end, obliquely in and back...	83					86	
Thickness of proximal end, obliquely in and forward..........	64					54	
Thickness of distal end, obliquely in and back..................	70					87	
Thickness of distal end, obliquely in and forwards..............	50					50	
Manus—							
Matacarpal II, length...........	185	250	200	245			220
" " maximum diameter proximal end....	39						
" " maximum diameter distal end.......	37						
Metacarpal III, length...........	226	330	220				265
" " maximum diameter proximal end......	49						
" " maximum diameter distal end........	50						
Metacarpal IV, length...........	225	330	215				280
" " maximum diameter proximal end.....	68						
" " maximum diameter distal end........	51						

COMPARATIVE MEASUREMENTS OF SHOULDER GIRDLE AND FORE LIMBS—*Cont.*

	I	II	III	IV	V	VI	VII
	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Metacarpal V, length	94	130	75	120			
" " maximum diameter proximal end	52						
" " maximum diameter distal end	35						
Phalanx II^1, length	75						
" " proximal width	45						
" " distal width	42						
Phalanx II^2, length	18						
" " width	25						
Phalanx II^3, length	64						
" " proximal diameter	37						
" " width of hoof	53						
Phalanx III^1, length	57						
" " proximal diameter	51						
" " distal diameter	47						
Phalanx III^2, length	21						
" " width	34						
Phalanx III^3, length	52						
" " proximal width	45						
" " width of hoof	58						
Phalanx IV^1, length	66						
" " proximal diameter	52						
" " distal diameter	53						
Phalanx IV^2, length	18						
" " width	34						
Phalanx IV^3, length	15						
" " width	21						
Phalanx V^1, length	60						
Phalanx V^2, length	32						
Phalanx V^3, length	18						
Phalanx V^4, length	10						

RIBS AND STERNAL BONES

Cervical ribs (Figs. 3 and 4) are borne by all the vertebrae of the neck except the atlas; they are of the usual double-headed type with the tuberculum fused to the postero-ventral side of the diapophysis at its extremity, and with the capitulum similarly and more completely fused to the parapophysis.

The rib of the axis, really the first but herein called the second to accord with the number of the vertebra, is different from those immediately posterior to it. As the bone was broken and displaced the following description can not be relied on absolutely. The posterior branch is relatively long, narrow, and very thin; it measures 100 mm. from its extremity to the tuberculum. The capitular branch is broad, flat, and extremely thin; apparently, it was attached to the relatively large and low-set parapophysis; by lateral expansion it merges with the posterior and tubercular branches; it measures 70 mm. from the capitulum to the tuberculum. This rib differs from the others in its greater length, more delicate structure, and in the fact that the three branches lie almost in one plane.

The remaining cervicals conform to a uniform structure but they show considerable variation. Of the anterior branches, the capitular is always the more important and increases gradually in length distally. The tubercular branch is slightly concave in its anterior margin and shows a fairly sharp point at the union with the capitular branch; this point is continued backwards as a gradually diminishing ridge on the face of the posterior branch.

The second to fifth cervicals are very much alike and have a slender and rather pointed posterior branch which measures about 85 mm. from its extremity to the tuberculum.

The sixth to tenth cervicals differ from the anterior ones in that the posterior branch is flattened dorso-ventrally instead of being evenly pointed. Measured from the tip of the posterior branch to the tuberculum this set of cervicals shows the following lengths: sixth, 70 mm.; seventh, 63 mm.; eighth, 54 mm.; ninth, 58 mm.; tenth, 68 mm. While there is no increase in length these ribs become gradually more robust distally. The capitular branch, measured in a straight line from the centrum immediately behind the parapophysis, increases gradually from 40 mm. in the sixth to 63 mm. in the tenth.

The eleventh and twelfth cervicals have pointed posterior branches resembling those of the more anterior ribs; measured

from the tuberculum these branches are respectively 80 mm. and 120 mm. in length. The capitular branches are posteriorly directed; measured as in the case of the previous set, they show lengths of 80 mm. and 97 mm. respectively.

The thirteenth cervical rib is a very much stouter bone resembling the first dorsal more than the twelfth cervical. It is at least 240 mm. long but its extremity is hidden under the scapula and can not be seen. This rib is considered as belonging to the cervical series because the capitular branch is well out of contact with the diapophysis, and because the postzygopophysis of its vertebra is distinctly cervical and not dorsal in character. There is little doubt, also, that both capitulum and tuberculum are firmly fused with their supports.

Dorsal ribs are borne by all the vertebrae of the series except the last. The tubercular branch is very short with a rounded termination; the capitular branch is very stout and is in fairly close contact with the antero-ventral side of the diapophysis. In no case can the manner of its attachment to the parapophysis be seen, but with the greater ribs, it must have a length of at least 160 mm.

The ribs are thicker and with a rather square edge on their anterior sides, whereas the posterior edge is thinner and more acute. The third to fifth ribs are the stoutest, with a maximum width of 38 mm.

The length of each rib is indicated in the following table:

	Length, mm.		Length, mm.
Dorsal rib No. 1	659	Dorsal rib No. 8	660+
" " " 2	885	" " " 9	633
" " " 3	861	" " " 10	532
" " " 4	912	" " " 11	304+
" " " 5	950	" " " 12	304
" " " 6	930	" " " 13	253
" " " 7	887	" " " 14	221
		" " " 15	171

Both *sternal bones* (Fig. 14) were found in natural position with their inferior edges in contact. Each bone consists of a laterally compressed, shaft-like, upper portion and a broader, blade-like, lower part. The shaft, gradually thickening, is

FIG. 14—Left sternal bone, external view. One fourth natural size.

continued downwards in the blade on the antero-exterior face of which it forms a distinct ridge. The posterior part of the blade is very thin and inclines inwards; therefore, it is not in the same plane as the laterally compressed shaft. The inner face is flatter than the outer in the shaft, and is slightly concave in the blade. The upper free end of the shaft is considerably expanded, particularly on the external side. The whole bone is slightly curved laterally and its anterior margin forms a sweeping concave curve.

MEASUREMENTS OF STERNAL BONES

	Left mm.	Right mm.
Total length	365	348
Width of expanded upper end	88	90
Minimum width of shaft	39	41
Maximum thickness of shaft	20	
Width of blade, diagonal	170	178
Thickness of blade at anterior ridge	45	
Thickness of posterior part of blade	8	

PELVIC GIRDLE AND HIND LIMBS

The pelvic girdle (Fig. 15) conforms to the usual trachodont type and is to be distinguished chiefly by the character of the prepubis. The figure and the measurements given in the tables require little additional description.

The *ilium* has the same general aspect as that of *Claosaurus annectens* figured by Marsh,[1] or that of *Stephanosaurus* (*Trachodon*) *marginatus*, Lambe.[2] The preacetabular portion is much narrower than the posterior, is rather tapering, and somewhat decurved, with a thick and rounded upper margin.

[1]16th Ann. Rep., U.S. Geol. Sur., Plate LXXIII.

[2]Con. Can. Pal., Geol. Sur. Can., Vol. III, Pt. II, p. 76.

Above the ischiac peduncle the superior margin of the bone folds outwards in a broad shelf which is separated from a considerable rugose area above the peduncle by a pronounced longitudinal groove. The posterior blade-like portion reaches its greatest length near the inferior border.

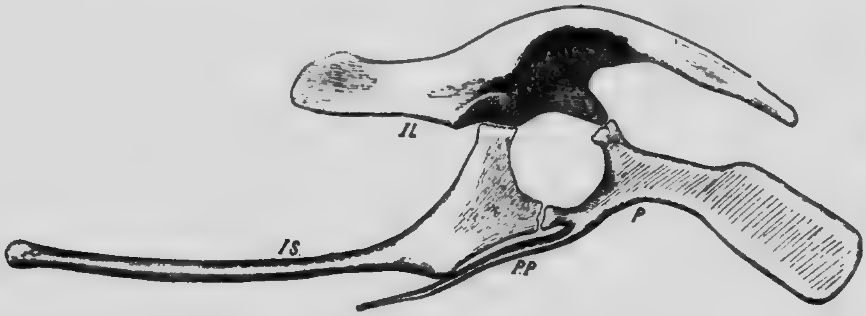


FIG. 15—Right pelvic girdle. About one fifteenth natural size.
IL, *ilium*; P, *pubis*; PP, *postpubis*; IS, *ischium*.

The *pubis* differs from that of other trachodonts in that the preacetabular portion or prepubis is more distinctly divisible into two parts: a proximal shaft-like section and a distal blade of which the inferior and superior margins are remarkably parallel. The width of the prepubis is less than usual, but its length is exceeded only by that of *Trachodon mirabilis*; its anterior end is less rounded than in the case of most trachodont pubes. The inferior branch for union with the ischium is slender and the area of contact small.

The postpubis is moderately long, relatively stout proximally, but thin and delicate towards the extremity where it is slightly expanded. The pubic notch, between the postpubis and the ischiac branch of the prepubis, is open and without any sign of being transformed into a foramen.

The *ischium* is a longer and more robust bone than the pubis; its proximal portion is flat or slightly convex externally and with a pronounced inward direction ventrally. This portion bears a wide surface for union with the postacetabular peduncle of the ilium, and a much narrower area for union with the pubis below the acetabulum. The superior margin of this proximal portion curves downwards and

backwards in a concave sweep passing gradually into the posterior shaft-like section. The inferior margin, also, is slightly concave from the union with the pubis backwards to

FIG. 16—A, right femur, external view, slightly restored; B, left femur, internal view, somewhat restored by comparison with left. One eighth natural size. gt, *great trochanter*; lt, *lesser trochanter*; 3t, *third trochanter*; ic, *inner condyle*; oc, *outer condyle*.

the distinct obturator process. Posterior to this process the inferior margin ra, idly approaches the superior and passes likewise into the shaft-like portion.

The elongated posterior part of the bone is flattened internally and is in contact with its fellow, almost, if not quite, as far forward as the obturator process. Externally it shows a rather sharp ridge a little ventral to the midline. The distal end is somewhat swollen, almost entirely on the ventral side.

The *femur* (Figs. 16 and 17) consists of a comparatively light shaft and extremities so expanded that the bone has a clumsy appearance. On the internal side the shaft is evenly rounded, somewhat contracted towards the proximal end, and curved distinctly forwards and inwards where it expands into the large rounded head. As the left femur was much injured by erosion and as the head of the right is still buried in the acetabulum it is to be understood that the dimensions and shape of the head as shown in Fig. 16 are open to correction.

Distally the shaft, seen from the internal side, maintains a fairly constant diameter until very near the end where it suddenly expands, much more posteriorly than anteriorly, into the very large inner condyle. This structure is comparatively flat internally and shows distinct longitudinal fluting near the rounded articular surface.

The external side of the shaft is less rounded and more flattened than the internal. Proximally there is a wide and thin expansion in the anterior position which is interpreted as the lesser trochanter although some authors would regard it as the greater trochanter. This flange-like extension continues around the upper external face of the bone and downwards on the postero-external side, there forming the greater trochanter. The two trochanters, therefore, lie almost in a plane on the external face of the bone; in fact, there is a slight concavity rather than a convexity between them, but it must be admitted that pressure may have affected the parts to some extent. The greater trochanter is thicker than the lesser and fades more gradually into the shaft internally. The proximal flange formed by the union of the

two trochanters overhangs the head and is separated from it by a pronounced wide and continuous concavity which is prolonged down the anterior side of the bone for a third of its length.

On the external side the shaft swells distally into a large outer condyle which is similar in position and shape to the inner, and, like it, is longitudinally fluted. An outward deflection of the posterior part of the outer condyle produces a distinct concavity on the external face.

The two condyles are separated by deep anterior and posterior depressions: the posterior is 65 mm. deep and is confined to the overhanging part of the condyles; the anterior is really deeper, perhaps as much as 85 mm., but as it is excavated in the distal end of the shaft proper and runs forward to the anterior margin, it is less conspicuous from the distal point of view. Neither intercondylar groove is closed, but the anterior groove shows a tendency in this direction as a distinct prominence is developed on the inner condyle which is apposed to a still stronger inflection on the outer. The anterior sides of both condyles show fluting as in the case of the inner and outer faces.

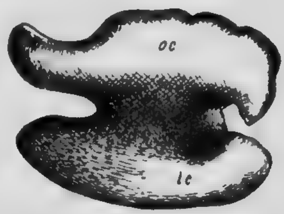


FIG. 17—Right femur, distal view. One eighth natural size. oc, *outer condyle*; ic, *inner condyle*.

The third trochanter is a prominent, elongated, plate-like extension on the posterior side of the shaft at about its midlength. Its greatest width is 68 mm. at a point somewhat below its centre. Owing to injury it is impossible to accurately describe this trochanter.

The *tibia* (Fig. 18) is a shorter bone than the femur; it is contracted in the shaft but greatly expanded at both ends. The proximal expansion is nearly antero-posterior while the distal is almost at right angles to that direction. This twist occurs in such a manner that the inner face proximally becomes the posterior face distally.

The proximal expanded end of the bone is thin anteriorly and turned outwards as a distinct enemial crest. On the

outer face, posterior to this crest, is a wide shallow depression followed by a robust inner condyle which seems to have a backward direction. The proximal end of the fibula over-

FIG. 18—A, left tibia, internal view; B, right tibia, external view. One eighth natural size.
i.c., *inner condyle*; o.c., *outer condyle*; e.c., *cnemial crest*; o.m., *outer malleolus*; i.m., *inner malleolus*.

laps this condyle laterally. A second condyle, separated from the first by a deep intercondylar notch, forms the postero-lateral angle of the bone.

The large proximal expansion fades into the shaft in long sweeping curves of which the posterior is the more concave. The distal expansion, from the outer viewpoint, shows a rather sharp edge running down to the extremity of the elongated outer malleolus.

The inner side of the bone shows the proximal expansion as a fairly flat surface turned sharply outwards at the enemial crest. The distal expansion, from this point of view, appears as a thicker and considerably shorter malleolus than the outer.

Viewed from the posterior side the distal end of the bone shows the longer external and shorter internal malleoli separated by a shallow depression. The face of the bone, in this direction, shows a rather sharp median ridge which slopes away gradually to the margins.

The *fibula* (Fig. 19) is a long and very slender bone, expanded proximally and rather less distally; the two expansions are not quite in the same plane. The proximal end is convex externally and concave internally, the concavity extending half way down the shaft.

FIG. 19—Left fibula; A, external, proximal, and distal views; B, internal view. One eighth natural size.

The distal end is flattened and striated on the postero-internal face where it comes in contact with the tibia.

Of the tarsal bones only the *astragalus* (Fig. 20) is known. This is a cap-like bone, hollowed proximally to fit over the inner malleolus of the tibia. There is an ascending point in front which fits in between the two malleoli and a more pronounced point behind the inner malleolus. The distal surface is well rounded antero-posteriorly, and is slightly concave laterally. Internally the surface slopes up to a rather sharp convex edge; externally the edge is thicker with a distinct articular surface for the calcaneum.

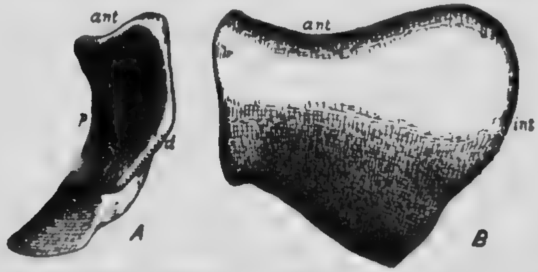


FIG. 20—Right astragalus. A, external view; B, distal view. One fourth natural size.
p, *proximal*; d, *distal*; ant, *anterior*; int, *internal*.

The *pes* (Figs. 21 and 22, and Plate VI) is of the usual trachodont type and presents no unique features. All six metatarsal bones were found, but a few of the phalanges were missing. Only one bone was unrepresented in either one foot or the other—the first phalanx of the fourth digit.

The metatarsals are all stout bones expanded at both ends. The middle bone is much longer and heavier than the other two of which the inner is the lighter.

Metatarsal II is much flattened vertically and greatly expanded in this direction at the proximal end. The internal face is rather smoothly convex transversely and evenly concave longitudinally. The external face is quite flat proximally where it is in close contact with metatarsal III; distally, it diverges and is more irregular. The anterior edge is rather sharp and runs up to a decided point about 65 mm. from the beginning of the distal articular surface. The posterior edge is fairly sharp and evenly concave longitudinally.

The proximal articular surface is strikingly flat and is very elongate vertically and compressed laterally. The distal articular surface is rhomboidal in outline with the upper

and lower sides of the rhombus inclined down and in. The articular facette is strongly convex above and concave transversely below.

Metatarsal III is much the heaviest bone of the pes; it is stout and shaft-like at midlength but expands at both ends. The proximal expansion is sub-triangular with a flat base internally and a rounded apex externally. The distal expansion is quadrangular to sub-rhomboidal in outline.

FIG. 21—Right metatarsus, anterior and proximal views. One eighth natural size.

II, second metatarsal; III, third metatarsal; IV, fourth metatarsal.

FIG. 22—Right metatarsus, posterior and distal views. One eighth natural size.

II, second metatarsal; III, third metatarsal; IV, fourth metatarsal.

The external aspect shows a distinct concavity in the distal expansion between the upper and lower margins. Proximally this depression passes into a distinct ridge which becomes the rounded apex of the sub-triangular head. The internal face is rather flat at the distal end and convex at midlength. Proximally it forms a broad flat triangle in a plane inclined upwards and outwards. This surface fits closely against the corresponding flattening on Metatarsal II.

The distal articular surface is continued well up on the anterior face; it is convex vertically and slightly concave laterally. The proximal articular surface is flat and sub-triangular in outline.

Metatarsal IV is a bone of very irregular shape, flattened dorso-ventrally in the shaft and expanded at both ends. The distal expansion is sub-rhomboidal and concave on all four sides; the internal concavity is deepest and sharpest causing lip-like tuberosities in the anterior and posterior positions. The external and posterior concavities are shallow and broad, and the anterior is but slightly developed.

Proximally the bone expands evenly on the anterior, posterior, and external sides rising to a rather sharp edge against the articular surface. Internally it is strongly excavated in a broad hollow which fits over the rounded apex of the triangular head of the third metatarsal. The floor of this hollow runs out on the internal side of the bone into a conspicuous roughened point a little above mid-length.

The proximal articular surface is slightly concave and sub-triangular to sub-quadrate in outline. The base of the triangle is internal and concave; the apex is external and very broadly rounded. The distal articular surface is rhomboidal in outline with concave sides it is strongly convex dorso-ventrally and slightly convex laterally.

The phalangeal formula is the same as other members of the *Trachodontidae* as follows:

Digit II with three phalanges, the third a hoof.
Digit III with four phalanges, the fourth a hoof.
Digit IV with five phalanges, the fifth a hoof.

Plate VI and the table of measurements require no additional description in the case of these small bones.

COMPARATIVE MEASUREMENTS OF PELVIC GIRDLE AND HIND LIMBS[1]

	I	II	III	IV	V	VI	VII
	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Ilium—							
Total length	1013	1160	1030+	1150	1035		1060
Preacetabular border to ant. end	430	480	410	470			
Width at pubic peduncle	215				205		320(?
Maximum width of ant. ramus	68						
Average width of posterior blade	117						
Pubis—							
Total length	1038	1150	630		1000	940	
Width of blade of prepubis	163	310	200	220	270		
Minimum width of prepubis	90				100	92	120
Length of prepubis	519	590	360	450	490	485	
Length of postpubis, from notch	532						
Width of distal part of postpubis	25						
Minimum thickness of postpubis	6						
Width of terminal swelling	25						
Thickness of terminal swelling	17						
Ischium—							
Length, distal end to pubic union	1026	1200	1090		1030		1140
Length, distal end to iliac union	988					1050	
Across iliac and pubic heads	240						340
Distal end to obturator process	873						
Width at obturator process	120						
Lateral thickness of distal swelling	65						

[1]For explanation of the numbers above the columns see page 41.

COMPARATIVE MEASUREMENTS OF PELVIC GIRDLE AND HIND LIMBS—*Cont.*

	I	II	III	IV	V	VI	VII
	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Isch[illegible]m—							
[illegible]ickness of [illegible]	62						
M[illegible] of the two is[illegible]hia [illegible] united	177						
Gi[illegible] of th[illegible] two dist[illegible] [illegible]	[illegible]5						
Femur—							
L[illegible] p[illegible]	1045	1150	1040	1170	1080	1182	
Leng[illegible], in[illegible] he[illegible]	1014					1169	
Breadth of upper extremity	209					246	
Antero-posterior diameter of inner condyle	292					300	
Antero-posterior diameter of outer condyle	262						
Thickness at condyles	210						
Middle of inner condyle to tip of third trochanter	504						
Thickness of shaft below head	90						
Tibia—							
Total length	943	1020	870	1000	1000	1018	1080
Width of proximal expansion	326	350?	310			272	
Minimum diameter of shaft	87						
Width of distal expansion	270					337	
Thickness of inner condyle	134						
Thickness of inner malleolus	88						
Thickness of outer malleolus	110						
Fibula—							
Length	878	970	820	920	950		1000
Width of proximal expansion	153	190	160				
Width of distal expansion	112	125	55				
Girth, 300 mm. from lower end	143						
Girth, 300 mm. from upper end	193						

COMPARATIVE MEASUREMENTS OF PELVIC GIRDLE AND HIND LIMBS—*Cont.*

	I	II	III	IV	V	VI	VII
	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Fibula—							
Thickness of proximal expansion	53						
Thickness of distal expansion	70						
Astragalus—							
Width, lateral	167						
Length, antero-posterior	213						
Greatest thickness	45						
Metatarsals—							
Metatarsal II, length	281	280	280	280	310		350
" " vertical diameter dis- end	135						
" " transverse diameter distal end	79	110		100			
" " vertical diameter proximal end	166						
" " transverse diameter proximal end	68	110		90			
Metatarsal III, length	363	420	340	370	380		430
" " vertical diameter distal end	89						
" " transverse diameter distal end	124	170	130	130			
" " vertical diameter proximal end	165						
" " transverse diameter proximal end	83-95	180	100	140			
" " minimum girth	232						

COMPARATIVE MEASUREMENTS OF PELVIC GIRDLE AND HIND LIMBS—*Cont.*

	I	II	III	IV	V	VI	VII
	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Metatarsal IV, length.....	278	330	275	300	320		340
" " vertical diameter distal end	89						
" " transverse diameter distal end	80	110		120			
" " oblique diameter distal end	173						
" " vertical diameter proximal end.....	112						
" " transverse diameter proximal end.....	84	85		100			
" " minimum girth....	195						

	I	II	III	IV	V	VI	VII
	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Phalanges—							
II¹. length.....................	130	130	130	120	140		
" proximal transverse width....	110						
" proximal vertical width......	82						
" distal vertical width.........	53						
" minimum girth.............	192						
II², length.....................	47	70	55	60	45		
" proximal transverse width....	75						
" distal transverse width......	70						
" proximal vertical width......	50						
" distal vertical width.........	35						
" girth at middle.............	175						
II³, length.....................	80	80	110		85		
" proximal transverse width....	58						
" width of hoof...............	58						
" proximal vertical width......	44						

COMPARATIVE MEASUREMENTS OF PELVIC GIRDLE AND HIND LIMBS—*Cont.*

	I	II	III	IV	V	VI	VII
Phalanges—	mm.	mm.	mm.	mm.	mm.	mm.	mm.
III[1], length	118	140	120	130	135		
" proximal transverse width	140						
" distal transverse width	114						
" proximal vertical width	82						
" distal vertical width	55						
" minimum girth	262						
III[2], length	33	60	50	40	40		
" proximal transverse width	110						
" distal transverse width	110						
" proximal vertical width	58						
" distal vertical width	45						
III[3], length	25	50	40	40	25		
" transverse width	90						
" proximal vertical width	43						
" distal vertical width	40						
III[4], length	80	100	100	100	90		
" proximal transverse width	76						
" proximal vertical width	40						
" width of hoof	103						
" girth above hoof	152						
IV[1], length		110	90	95	110		
IV[2], length	20	40	30	25	25		
" transverse width	71						
" vertical width	50						
IV[3], length	18	30	20	22	20		
" transverse width	70						
" vertical width	50						
IV[4], length	14	45	30	25	17		
" transverse width	63						
" vertical width	38						
IV[5], length	85	100	90	105	95		
" proximal transverse width	55						
" proximal vertical width	44						
" width of hoof	73						
" girth above hoof	126						

MUSCULATURE

The ossified tendons of muscles so characteristic of this type of dinosaur are preserved in unusual perfection along the vertebral column from the fourth dorsal to the nineteenth caudal vertebra. In all, 93 muscles were observed; but it is probable that this number would be increased, even in the part of the animal preserved, if the tendons lost or hidden in the matrix were added.

The drawing, Plate I, shows with reasonable accuracy the course and position of the tendons actually observed, without any attempt at restoration. The necessity of leaving some matrix for the support of the outer muscles and some patches of skin which it was thought advisable to retain has interrupted the continuity of the muscles in certain cases.

The tendons are round or slightly oval in the major part of their length, and, on the average, are about 7 mm. in diameter; they become thin and wide towards the extremities, in some cases reaching a diameter of 18 mm. While these flattened extremities are in some cases closely applied to the neural spines, in others they cease a little short of the spine to which they belong. It is likely that the actual connection was effected by short unossified endings.

The muscles are arranged in three major divisions which I propose to indicate as "sets"; the sets are divisible into "groups," and in one instance the group is resolved into "series." The anterior ends are regarded as the "origins," and the posterior ends as the "insertions." D, S, and C are used to designate dorsal, sacral, and caudal vertebrae respectively. The number following the letter indicates the position of the vertebra in the series to which it belongs. In the following tables the muscles are numbered in sets, thus "III$_4$" is the fourth muscle of the third set. The second column in the tables indicates the actual, observed extent of the tendon; the third column shows the probable extent which is deduced from the observed extent of the more perfect tendons of the group in question; the fourth column shows in millimetres the length of the part actually visible.

MUSCLES OF SET I

The first set includes all those muscles which extend backwards and downwards from near the summits of the neural spines. These tendons underlie all others and with a few exceptions are closely applied to the sides of the neural spines throughout their whole extent. Thirty-six muscles are included here although five of them are inferred rather than observed in position. The anterior members of the set are of medium length, those of the middle region are somewhat longer, and the posterior members are much shorter and more highly inclined. Two groups can be distinguished—an anterior group of longer tendons and a posterior group of shorter tendons. The latter does not follow the former in regular order but the two groups overlap in the posterior part of the sacral region.

The first group is capable of an indistinct division into two series—an anterior regular series, and a posterior series of less regular development.

Set I, Group 1, Series 1.

There are eleven, or possibly twelve, muscles in this series. The insertions of the first four can not be seen owing to a patch of skin which covers them. The last tendon of the series could, with equal reason, be placed in the second series. Calculated from the more perfect muscles observed, the average length is 554 mm. Each tendon stretches across seven neural spines inclusive and is closely applied to the sides of the spines throughout its whole length.

TENDONS OF SET I, GROUP 1, SERIES 1

No.	Observed range	Probable true range	Observed length, mm.	Notes
I 1	D 4—..	D 4—D10	40	Covered distally
I 2	D 5—..	D 5—D11	30	" "
I 3	D 6—..	D 6—D12	20	" "
I 4	D 8—..	D 7—D13		Broken anteriorly
I 5	D 8—D14	D 8—D14	560	
I 6	D 9—D14	D 9—D15	450	Broken posteriorly
I 7	D10—D16	D10—D16	570	
I 8	D11—S1	D11—S1	560	
I 9	D12—S2	D12—S2	530	
I 10	D13—S3	D13—S3	545	
I 11	D14—S4	D14—S4	560	
I 12	D15—S5	D15—S5	625	Might go to Series 2

Set 1, Group 1, Series 2.

This series begins with some very long members which diverge distally from those of Series 1 and are inserted nearer to the bases of the neural spines. The posterior members of the series are irregular, shorter, and probably not inserted on the neural spines distally, they lie between some of the anterior tendons of Group 2.

TENDONS OF SET I, GROUP 1, SERIES 2

No.	Observed range	Probable true range	Observed length, mm.	Notes
I 13	D16—S7	D16—S7	700	
I 14	S1—C1	S1—C1	870	
I 15	S7—C3	S7—C3	435	
I 16	C2—C7	S9—C7	350	Inserted on transverse process of C7

Set 1, Group 2.

This group of tendons begins with some very small members in the sacral region; the origins are to be seen but the insertions are hidden under the muscles of Set II. The posterior muscles are heavier, but, in most cases, neither the origin or insertion is clearly seen.

There is little doubt, however, that all the muscles of the group extend across four spines inclusive with a length of 300 to 400 mm. In the part of the animal preserved there are fifteen of these tendons, but as five more were in all probability present they are included in the table, making 20 in all.

TENDONS OF SET I, GROUP 2

No.	Observed range	Probable true range	Length	Notes
I 17	S3—S4	S2—S5		
I 18	S4—S5	S3—S6		Hidden distally
I 19	S4—S7	S4—S7		Hidden distally
I 20	S6—S7	S5—S8		
I 21	S6—S7	S6—S9		
I 22	S6—S7	S7—C1		
I 23	S8—C2	S8—C2	300	
I 24	C2—C3	S9—C3		
I 25	C3—C4	C1—C4		
I 26	C4—...	C2—C5		All hidden anteriorly under muscles of Set II
I 27	C5—...	C3—C6		
I 28	C6—...	C4—C7		
I 29	......	C5—C8		Lost entirely
I 30	......	C6—C9		Lost entirely
I 31	C8—C10	C7—C10		
I 32	C8—C9	C8—C11		
I 33	......	C9—C12		Lost entirely
I 34	......	C10—C13		Lost entirely
I 35	......	C11—C14		The broken piece on C9 probably represents one of these lost tendons.
I 36	C13—	C12—C15		

MUSCLES OF SET II

This set includes all those tendons which run backwards and upwards to insertions on the sides of the neural spines near their summits. Such insertion is observed on every neural spine from D7 to C19 leading to the conclusion that these tendons were regularly developed, one for each spine, over the 30 vertebrae in question. The anterior ends seem to be less regular and as they are more affected by distortion it is difficult to state their exact limits; nevertheless, it is

reasonably certain that the origins of the more anterior members are on the transverse processes and that distally there is an increasing tendency for them to be situated on the neural spines. In no case was a muscle seen to actually arise from a transverse process; it must be admitted, therefore, that the free and irregular anterior endings may be entirely due to the tendons having been torn away from a normal origin near the base of the neural spines. According to the location of the origin it is possible to divide the set into seven groups to which may be added an eighth to include a single abnormal tendon. Excepting this one, all the tendons are external to those of Set I.

Set II, Group 1.

Nine tendons are included in this group; they are all to be seen at their posterior ends, but only in the case of the last two could the origin be made out with certainty. These extend over nine spines with the origin apparently on the transverse process. The assumption of a similar origin and extent for the first seven is scarcely justified but this procedure has been followed in making the table below. It will be observed also that the probable insertion is given in each case on the spine posterior to the observed insertion; this was found to be necessary in order to preserve the continuity of the group and it is thoroughly justified by the fact that some of the posterior ends actually overhang distally the spines to which direct observation would credit them.

TENDONS OF SET II, GROUP 1

No.	Observed range	Probable range	Observed length, mm.	Notes
II 1	—D6	D1—D7	400	
II 2	—D7	D2—D8	400	
II 3	—D8	D3—D9	400	
II 4	—D9	D4—D10	300	
II 5	D 5—D10	D5—D11	400	
II 6	D10—D11	D6—D12	150	
II 7	D10—D12	D7—D13	200	Under patch of skin
II 8	D 6—D13	D6—D14	775	
II 9	D 7—D14	D7—D15	690	

Set II, Group 2.

This group consists of only one muscle which differs from all others of the set in that it lies internal instead of external to the tendons of Set I. Further the origin seems to be on a neural spine near its base instead of on the transverse process as in the case of Group 1.

TENDON OF SET II, GROUP 2

No.	Observed range	Probable true range	Observed length, mm.	Notes
II 10	D11—D14	D11—D16		Origin low on spine

Set II, Group 3.

Each of the ten tendons of this group extends across seven neural spines. The anterior ends are divergent and the origins are well down on the spines; the posterior parts are close together and almost parallel with one another. The average length, calculated from the more perfect tendons only, is 623 mm.

TENDONS OF SET II, GROUP 3

No.	Observed range	Probable true range	Observed length, mm.
II 11	D11—S1	D11—S1	625
II 12	D12—S1	D12—S2	505
II 13	D13—S3	D13—S3	610
II 14	D15—S4	D14—S4	450
II 15	S3 —S5	D15—S5	220
II 16	D16—S6	D16—S6	636
II 17	S1—S6	S1—S7	485
II 18	S2—S7	S2—S8	460
II 19	S3—S8	S3—S9	535
II 20	S5—S9	S4—C1	470

Set II, Group 4.

The tendons of the fourth group resemble those of the third in having both the origins and insertions on the sides of the neural spines and in diverging anteriorly; they differ in extending across nine spines instead of seven with a consequent greater length, probably 800 mm.

TENDONS OF SET II, GROUP 4

No.	Observed range	Probable true range	Observed length, mm.	Notes
II 21	S4—C1	S5—C2	775	Evidently longer
II 22	S4—C3	S4—C3	800	
II 23	S5—C3	S5—C4	720	Evidently longer

Set II, Group 5.

The tendons of this group differ in that they extend across ten spines. The anterior member is very long as its origin is low down on the broad sacral spine.

TENDONS OF SET II, GROUP 5

No.	Observed range	Probable true range	Observed length, mm.	Notes
II 24	S5—C5	S5—C5	835	
II 25	S6—C6	S6—C6	735	
II 26	S7—C7	S7—C7	730	

Set II, Group 6.

The five muslces of this group have an average length of 647 mm. and extend over nine spines. They differ also in that they are approximately parallel and close together throughout their course; in consequence, the origins are higher up on the spines. The last member, however, is separated by a considerable interval from the rest.

TENDONS OF SET II, GROUP 6

No.	Observed range	Probable true range	Observed length, mm.	Notes
II 27	C4—C8	S9—C8	310	Ant. hidden
II 28	C1—C9	C1—C9	660	
II 29	C2—C10	C2—C10	660	
II 30	C3—C11	C3—C11	645	
II 31	C4—C12	C4—C12	626	

Set II, Group 7.

The tendons of this group seem to extend across seven spines. The anterior ends are very differently situated from those of the previous group as they are free from the spines with the origins possibly on the dorso-lateral sides of the vertebrae. As the origins were in no case actually seen it may well be that the unusual position of the anterior ends is due to the tendons having been torn away from a more normal attachment on the spines.

TENDONS OF SET II, GROUP 7

No.	Observed range	Probable true range	Observed length, mm.	Notes
II 32	C7—C13	C7—C13	600	Origin well in on arch
II 33	C8—C13	C8—C14	580	Origin farther out on arch
II 34	C9—C14	C9—C15	410	Origin still farther out on arch

Set II, Group 8.

As in the last group the tendons extend over seven spines but the origins are again low down on the sides of the spines.

TENDONS OF SET II, GROUP 8

No.	Observed range	Probable true range	Observed length, mm.
II 35	C10—C14	C10—C16	290
II 36	......	C11—C17	
II 37	C12—C14	C12—C18	120
II 38	C13—C14	C14—C19	60

MUSCLES OF SET III

The muscles of this set are developed in connection with the ilium and the transverse processes of the vertebrae; in a few cases only is the insertion so far in that a connection with the neural arch or the base of the spine is suggested. Few, if any, of these tendons show both origin and insertion; their tortuous course, likewise, indicates displacement and

renders their original position difficult to determine. The set is divisible into three groups: an anterior group associated with the transverse processes of the anterior dorsal vertebrae, a second group extending backwards from the transverse processes of the posterior dorsal vertebrae to the superior margin of the ilium, and a third or posterior group arising either from the end of the ilium or from transverse processes in the vicinity and stretching backwards to the transverse processes of the caudal vertebrae.

Set III, Group 1.

Five muscles were observed in this group; they run from the transverse processes backwards. The anterior members are inserted on their respective vertebrae in the angle at the base of the neural spine, thus merging into the first group of the second set. The posterior members are inserted farther out, on the dorsal aspect of the vertebrae or well in on the transverse processes. While rather uncertain, on account of the doubtful insertions, it is likely that each tendon extends across six vertebrae inclusive, with an average length of about 400 mm.

TENDONS OF SET III, GROUP 1

No.	Observed range	Probable true erang	Observed length, mm.	Notes
III 1	D7—D12	D7—D12	390	Origin on side of trans. proc. Insertion on neural arch?
III 2	D8—D13	D8—D13	460	Origin near tip of trans. proc. Insertion on neural arch?
III 3	D9—D14	D9—D14	420	Origin near tip of trans.proc. Insertion on dorsal side of vertebra.
III 4	D11—D15	D10—D15	370	Origin near tip of trans. proc. Insertion on dorsal side of vertebra
III 5	D12—D16	D11—D16	370	Origin near tip of trans. proc. Insertion on base of trans. proc.

Set III, Group 2.

Each of the six tendons of this group arises near the extremity of the transverse process to which it belongs. The anterior two seem to be inserted on transverse processes; the posterior four are inserted close together in a groove on the superior edge of the ilium over the fourth and fifth sacral vertebrae.

TENDONS OF SET III, GROUP 2

No.	Observed range	Probable true range	Observed length, mm.	Notes
III 6	D13—	D13—S2 or S3	. .	
III 7	D13—S3	D13—S3 or S4	410	
III 8	D14—S5	D15—S5	410	Inserted on ilium
III 9	D15—S5	D15—S5	390	Inserted on ilium
III 10	D16—S5	D15—S5	365	Inserted on ilium
III 11	—S5	D16—S5	. . . . . .	Beneath others at insertion on ilium

Set III, Group 3.

The tendons of the third group terminate anteriorly in a very hard matrix which leaves their point of origin in great doubt. The general course, however, is suggestive of an origin on the posterior border of the ilium or far out on the transverse processes of the posterior sacral vertebrae. The tendons are long and more slender than those of the other sets; they seem to have a range over ten vertebrae and to be inserted on the transverse processes of the caudal vertebrae.

TENDONS OF SET III, GROUP 3

No.	Observed range	Probable true range	Observed length, mm.	Notes
III 12	S9—C4	S4—C4	350	Anterior end lost
III 13	S9—S5	S5—C5	400	Anterior end lost
III 14	S6—C6	S6—C6	700	
III 15	S7—C7	S7—C7	680	
III 16	S8—C8	S8—C8	640	
III 17	C1—C9	C1—C9	600	

In addition are two tendons which do not fall easily into any of the groups: the first of these might be ascribed to Set III, Group 3, and the second to Set II, Group 7. The first appears in the matrix outwards from the neural spine of C1 and extends to about half way up the neural spine of C5, 330 mm. The second seems to arise from the transverse process of C6 and to reach the neural arch of C9, 210 mm. The tendon was probably much longer posteriorly.

INTEGUMENT

Many skeletons of trachodont dinosaurs are accompanied by impressions which accurately portray the character of the epidermal covering. The most famous of these discoveries is the "dinosaur mummy," a skeleton of *Trachodon annectens* in which the greater part of the epidermal structure is revealed. This skeleton has been described in detail by Dr. Osborn.[1] Lambe, also, has described and figured a number of skin impressions from the Cretaceous rocks of Alberta.[2]

Regarding *Trachodon annectens* Dr. Osborn states: "Properly speaking the skin is not squamate, or imbricating, as in the lizards, but is rather tuberculate. . . . In all parts of the the body where the impressions are preserved, the epidermis was evidently covered with a pattern composed solely of tubercles, which were mainly of two kinds: (1) Small, rounded tubercles = ground plan, uniformly distributed. (2) Large 'pavement' tubercles, irregularly pentagonal in outline = raised pattern, diversely distributed."

Both Osborne and Lambe hold the opinion that these epidermal impressions are distinctive for each species and that they will eventually prove of the greatest service in the practical identification of specimens.

Impressions of the skin of *Kritosaurus incurvimanus* (Plate VII) were observed in the following regions: (1) Cervical, (2) Scapular, (3) Mid-rib, (4) Dorsal spines 7 to 9, (5) Dorsal spines 14 to 17.

[1]Integument of the Iguanodont Dinosaur *Trachodon*, Henry Fairfield Osborn, Mem., Am. Mus. Nat. Hist., New Series, Vol. 1, Part II.

[2]Ottawa Naturalist, Vol. XXVII, No. 10.

(1) The skin on the under side of the neck has been thrown into folds the impressions of which are very indistinctly preserved over a length of about 18 inches. Throughout this area no trace of pattern could be seen, all the tubercles being of polygonal outline, somewhat variable in size but occurring to an average number of three in the space of ten millimetres. These impressions had to be sacrificed in order to expose the cervical vertebrae.

(2) A small patch of skin at about mid-length of the scapula shows the same sort of ground plan, but the tubercles are uniformly smaller, occurring to the number of four in the space of ten millimetres.

(3) Several small patches of skin are preserved in the mid-rib region. They all show tubercles of about five millimetres in diameter, with deeply impressed, somewhat sinuous, polygonal boundaries. Among these larger tubercles are scattered a few smaller ones without any sign of regular arrangement. At intervals varying from 40 to 60 mm. occur sub-conical elevations measuring 12 mm. by 15 mm. (Raised pattern of Osborn, limpet-like elevations of Lambe.) The little cone is made up of about twelve convex sections which converge to a rounded apex. Surrounding the elevation is a ring of ten of the ordinary tubercles.

(4) A patch of skin over the neural spines of dorsal vertebrae seven to nine shows a ground plan of tubercles like that of the mid-rib region but somewhat finer, as 2.5 to 3.5 tubercles occur in the space of 10 mm. The limpet-like elevations occur here, likewise, and the general appearance is very like that figured by Lambe for the caudal region of *Stephanosaurus marginatus* (*Plate XVI, op. cit.*). In the dorsal region of Lambe's species the limpets are very much larger.

(5) Covering the neural spines of dorsal vertebrae fourteen to seventeen is a well preserved patch the ground plan of which is very like that of the more anterior dorsal region described above. Here, however, there seems to be none of the limpet-like elevations, but other dermal structures are developed which are different from anything hitherto observed in a trachodont dinosaur.

Along the median line of the back are conspicuous dermal elevations comparable in structure to the raised elements in the patches of skin already described; they are, however, of such great size as to assume the character of special dermal callosities. Two of these structures, and part of a third, are preserved, indicating that a row of them extended along the back, at least in the dorsal region.

The best-preserved callosity is situated above the fifteenth and sixteenth dorsal spines; it is 125 mm. long, 60 mm. high, and probably 50 or 60 mm. thick. From its posterior edge to the similar edge of the next callosity distal to it is 210 mm. indicating that there is no relation between the callosities and the spines. The ordinary skin continues across the median line of the back between the callosities but it terminates against the base of the callosity in a sharply defined, infolded line.

These peculiar elevations resemble low, laterally compressed cones with the apex posterior to the middle. The sides of the cones are vertically fluted in a manner to suggest that the flutings represent elongated tubercles of about the same diameter as those of the neighbouring skin. Towards the apex the flutings merge into a tuberculate surface not unlike that of the ground plan.

INDEX

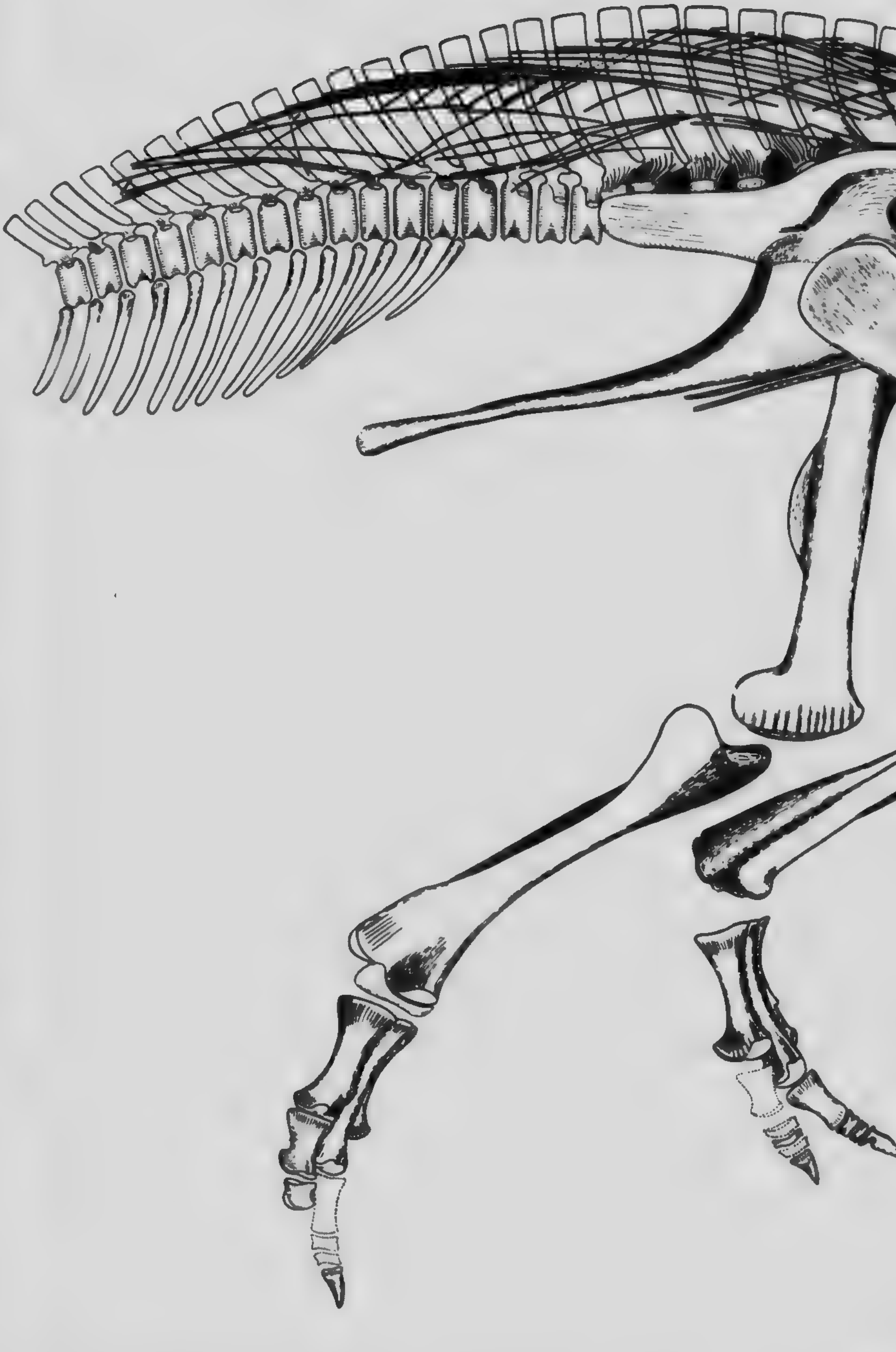
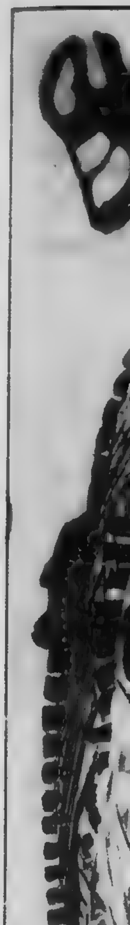


PLATE I.—KRITOSAURUS INCURVIMANUS. This figure indicates the position of the variou
No bones have been restored except where necessary to show connections and such bones are dot
The figure is designed to show the relation of the various parts and the musculature. Great accu

PLATE

PLATE I.

various parts of the skeleton as found, except that the bones of the hind limbs have been assembled
es are dotted. Parts of the vertebral column hidden in the matrix have been drawn in provisionally.
Great accuracy in the individual bones has not been attempted. About one-fifteenth natural size.



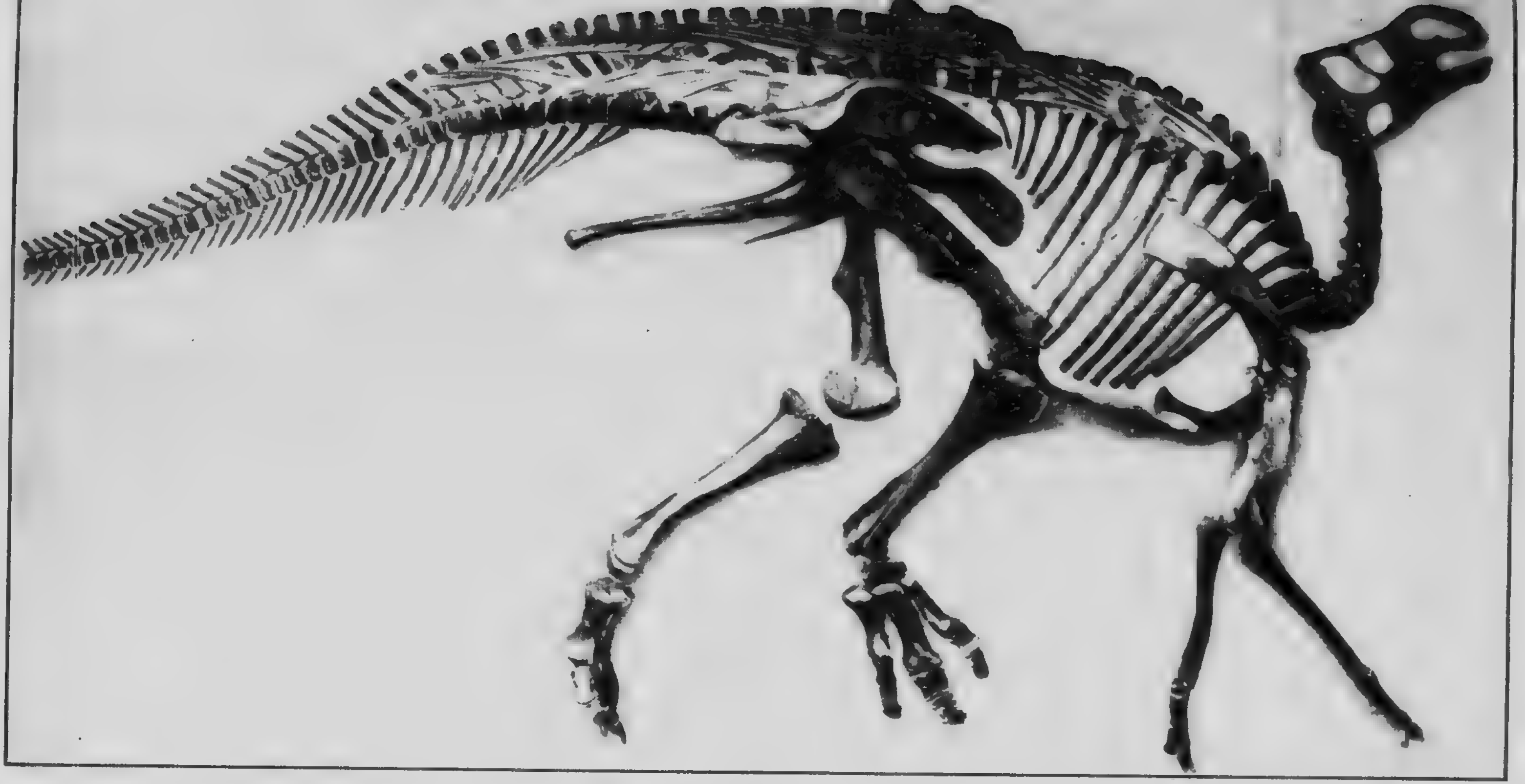


PLATE II.

PLATE II. —KRITOSAURUS INCURVIMANUS. The skeleton as mounted in the Royal Ontario Museum of Palaeontology. The position of the head and of the limbs has been altered, and restorations have been made of the missing bones of the pes, the anterior part of the head, and the extremity of the tail. About one-thirtieth natural size.

PLATE
sixth natur
one-fourth
Boc, *basioc*
sphenoid;
M, *maxilla*
Pa. sp, *par*
presphenoid
right pteryg
foramina.

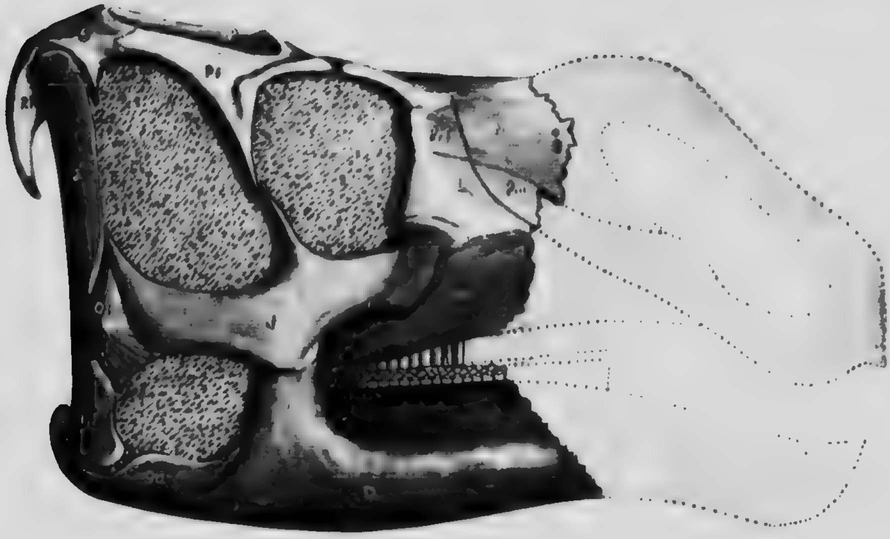


PLATE III. FIGURE 1.

PLATE III. FIGURE 2.

PLATE III.—KRITOSAURUS INCURVIMANUS. Figure 1, right side of head, one-sixth natural size; Figure 2, left side of head with temporal arches, jugal, etc., removed; one-fourth natural size: a, *foramen for blood vessel*; b, *foramen for blood vessel*; A, *articular*, Boc, *basioccipital*; Boc. Tub, *basioccipital tubercle*; Bpt.Pr, *basipterygoid process of basisphenoid*; D. *dentary*; F, *frontal*; Fe. ov, *fenestra ovalis*; J, *jugal*; L, *lachrymal*; Mx. and M, *maxilla*; N, *nasal*; OSP, *orbitosphenoid*; P and Pa, *parietal*; P.P., *paraoccipital process*; Pa. sp, *parasphenoid*; Pf, *postfrontal*; Pre. f and Prf, *prefrontal*; Pm, *premaxilla*; Pre. sp *presphenoid*; Pl. Pt. *palatal portion of pterygoid*; Q, *quadrate*; Qj, *quadrato-jugal*; R. Pt, *right pterygoid*; R.Q, *right quadrate*; S, *squamosal*; Sa, *surangular*; II to XIII, *nerve foramina*.

PLATE
from above,
natural size;

b.p, *basi*
f.m, *foramen*
postfrontal;
quadrato-juga

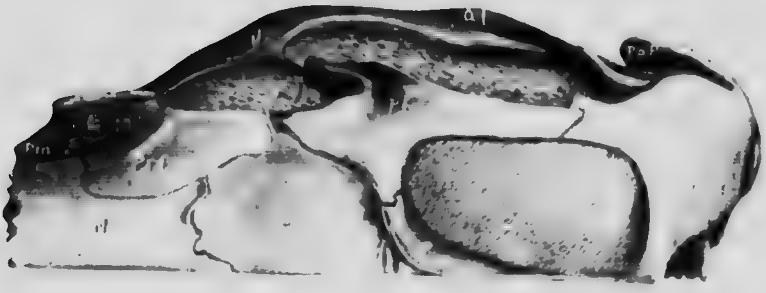


PLATE IV. FIGURE 1.

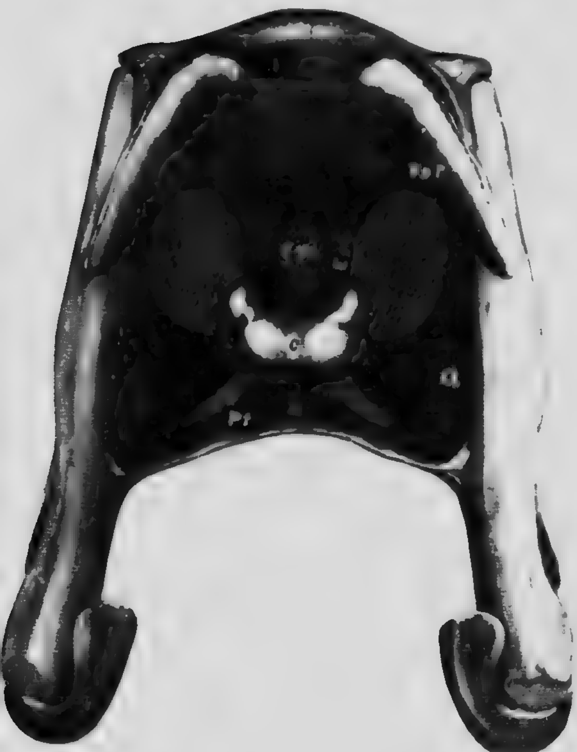


PLATE IV. FIGURE 2.

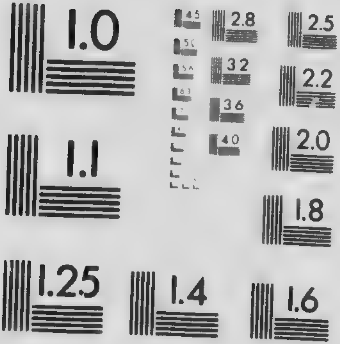
PLATE IV. FIGURE 3.

PLATE IV.—KRITOSAURUS INCURVIMANUS. Figure 1, right half of head viewed om above, one-fourth natural size; Figure 2, posterior view of head, one-fourth tural size; Figure 3, mandibular tooth, twice natural size:

b.p, *basipterygoid process of basisphenoid*; c, *occipital condyle*; Eco, *exoccipital*; F, *frontal*; n. *foramen magnum*; J, *jugal*; L, *lachrymal*; N, *nasal*; P, *parietal*; Pt, *pterygoid*; Pf, *stfrontal*; Prf, *prefrontal*; PoP, *paraoccipital process*; Pm, *premaxilla*; Q, *quadrate*; Qj, *adrato-jugal*; S, *squamosal*; t, *basioccipital tubercle*.

MICROCOPY RESOLUTION TEST CHART

ANSI and ISO TEST CHART No. 2



APPLIED IMAGE Inc

manu
size.

PLATE V, FIGURE 1.

PLATE V, FIGURE 2.

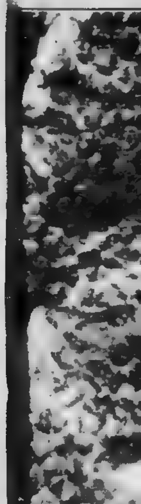
PLATE V.—KRITOSAURUS INCURVIMANUS. Dissociated phalanges of left manus; Figure 1, anterior view; Figure 2, posterior view. One-third natural size.

rig
na

PLATE VI. FIGURE 1

PLATE, VI FIGURE 2.

Plate VI.—Kritosaurus incurvimanus. Dissociated phalanges of right pes; Figure 1, anterior view; Figure 2, posterior view. One-fourth natural size.



...ate VII.
...fteenth do...
...th dors. I spi...

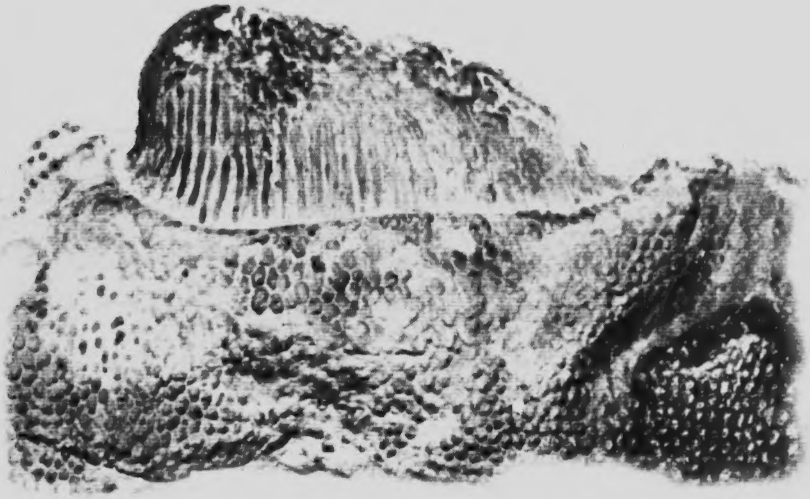


PLATE VII, FIGURE 1.

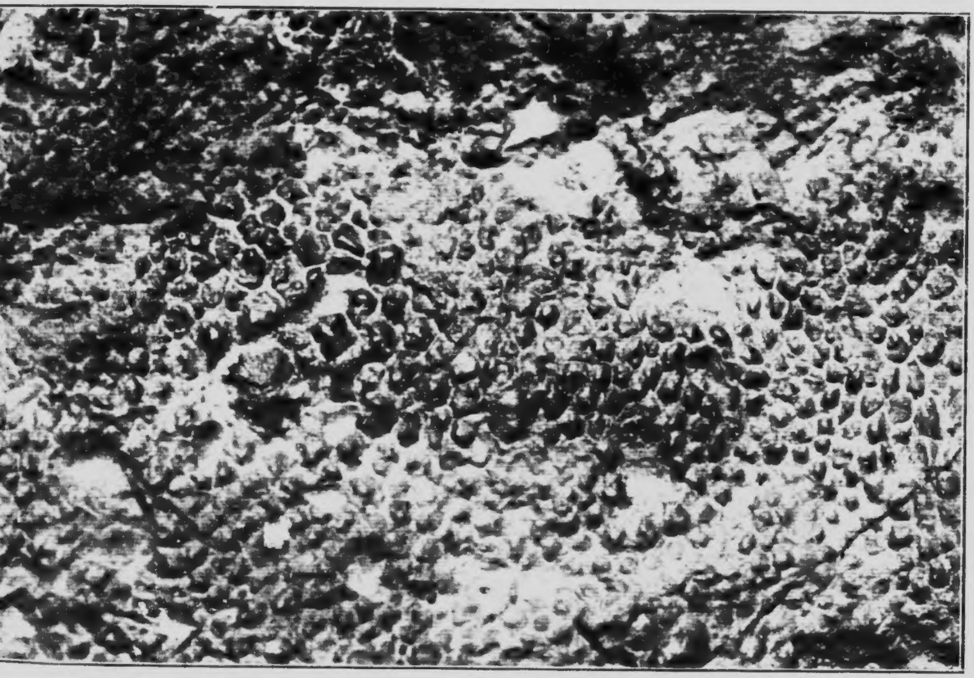


PLATE VII, FIGURE 2.

[P]LATE VII.—KRITOSAURUS INCURVIMANUS. Figure 1, median dermal callosity above the fourteenth [and] fifteenth dorsal spines. One-half natural size. Figure 2, skin impression over the seventh and [eight]h dorsal spines. Natural size

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